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ABSTRACT

The number of secondary schools, colleges, and universities offering courses in wind energy machine construction, repair, and installation, continues to increase. It is the purpose of this unit to include the study of wind energy conversion systems (WECS) as an integral part of related vocational and technical curriculum materials. The unit's overview identifies the major concepts to be covered and gives a brief description of the subject matter related to each concept. The major topics addressed in the document are: (1) an historical analysis of wind energy; (2) basic theory; (3) site analysis; (4) machine design fundamentals; (5) support structures; (6) wind energy utilization; and (7) related factors. The concept outline overview lists all of the concepts covered, along with suggested teaching times. Educational objectives and suggested instructional strategies are provided for each topic. An evaluation section provides techniques designed to measure the degree to which the objectives have been accomplished. A bibliography of other publications and audio-visual materials is provided, along with 29 overhead transparency masters that are referenced for use with certain instructional activities. (TW)

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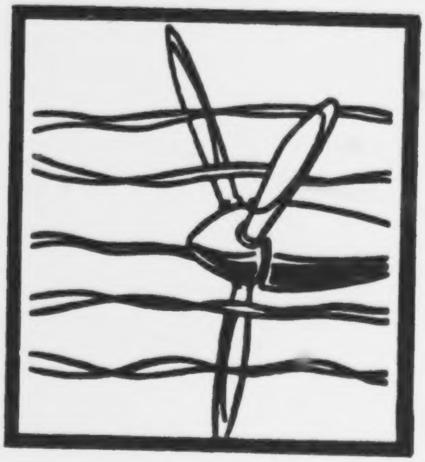

a unit of instruction

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WIND ENERGY CONVERSION SYSTEMS

a Unit of Instruction

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November 1982

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Project staff and participants look forward to your use of these pilot materials and hope you will feel free to suggest improvements.

Robert D. Weber
Project Director and Associate Professor
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FOREWORD

This document is one of four produced for the New Jersey Division of Vocational Education and Career Preparation by the Center for Energy Conservation at Trenton State College, Trenton, New Jersey. In addition to the four documents, four filmstrip/cassettes were also produced. The written documents and media packages deal with one of the following technologies:

1. Solar Heated Domestic Hot Water Systems
2. Solar Heated Space Systems
3. Wind Energy Conversion Systems
4. Heating with Solid Fuels

Curriculum materials were produced over a six month period by selected secondary school, industrial education teachers whose efforts were coordinated by a consultant from one of the state colleges. In all cases, both the teachers and the college consultant who served as the group leader, were selected for their experience and expertise in the particular technology being addressed. The filmstrip/cassette packages were developed and produced by technicians from the Center for Energy Conservation. The preliminary scripts were carefully reviewed and edited by the college consultants, project director and an industrial representative before being finalized.

During the 1980-81 school year each one of the units of instruction was pilot tested in a selected industrial education program within the State of New Jersey.

Further information regarding the availability of these curriculum materials can be obtained by writing to the address listed below:

Vocational-Technical Curriculum Lab
Rutgers - The State University of New Jersey
Building 4103 - Kilmer Campus
New Brunswick, New Jersey 08903

GUIDE FOR USING THIS DOCUMENT

This document attempts to organize a complex body of knowledge into teachable units. Information in the document has been arranged so that the reader is first exposed to the "big picture" or framework of the area under discussion. Then the reader is gradually introduced to the component parts of the package. This is accomplished by arranging the information in the following manner:

INTRODUCTION

The introduction provides the reader with basic information on the design and application of the curriculum materials in the document.

UNIT OVERVIEW

The unit overview identifies the major concepts to be covered and a brief description of the subject matter related to each major concept. A suggested period of time for teaching the subject matter has also been included in the unit overview.

CONCEPT OUTLINE OVERVIEW

In this section, the reader can examine more extensively a taxonomy or subject-matter outline of all major concepts. The outline provides a complete listing of the concepts to be covered along with suggested teaching times. Most of the major concepts have been broken down or outlined to the third level, using the numerical system listed below:

1.0 Designates a major or first level.
1.1 Designates a second-level concept.
1.1.1 Designates a third-level concept.

EDUCATIONAL OBJECTIVES

Educational objectives for each major concept are grouped together and can be located by referring to the Table of Contents. Educational objectives, derived from the third level concepts, are numbered accordingly. For example, a third-level concept (1.1.1) might have two objectives which would, therefore, be numbered as 1.1.1.1 and 1.1.1.2.

EDUCATIONAL OBJECTIVES WITH INSTRUCTIONAL STRATEGIES

In this section, each page focuses on a specific third-level concept. The third-level concept will be identified in relationship to the second- and first-level concepts in order to maintain continuity. Educational objectives pertaining to the third-level concept will then be listed. Finally, suggested instructional strategies useful to accomplish the listed objectives are recorded. The strategies are labeled a, b, c, etc. and can be used individually by the teacher or grouped together to facilitate accomplishing the listed objectives.

EVALUATION

This section provides suggestions for evaluating how much has been learned and the degree to which objectives have been accomplished.

BIBLIOGRAPHY

The bibliography serves as a resource guide and contains the following:

1. Overhead Transparency Masters
   These masters can be used to make overhead transparencies. In most instances, the transparency master has been identified for use with a particular instructional strategy.

2. Publications/References
   A list of books and magazines pertinent to the subject matter or related to an instructional strategy are included in this section. References made to publications in the text of this document are abbreviated and the reader is requested to check the bibliography for a more complete documentation.

3. Films, Slides, and Filmstrips
   A list of instructional media which could be used for instruction is included in this section.

   Here again, media referred to in the text of this document are abbreviated and the reader should check the bibliography for more complete documentation.

INTRODUCTION

Wind Energy Conversion Systems

It appears that wind energy will play a significant role in our future power generating schemes. The number of secondary schools, colleges and universities offering courses in wind energy machine construction, repair and installation continues to increase. It is the purpose of the unit of instruction to include the study of wind energy conversion systems (WECS) as an integral component of related vocational-technical curriculum materials. The material lends itself to interpretation at both the lecture and laboratory level by providing students with theoretical and practical knowledge of wind energy systems. Such knowledge helps to prepare students for critical choices in the future. The object of this coursework then, is to enable students to gain insights into components and features of wind energy devices that set them apart from other power generating schemes. In so doing, problem solving situations are encountered by students requiring the application of creative thinking to the phases of design, construction, and analysis of wind energy devices.

The unit of instruction for WECS is presented in what the curriculum group felt was a logical sequence. The teacher need not, however, feel bound to follow this sequence if rearrangements are deemed to be more beneficial for specific teaching situations.

In addition, no single source text is suggested for either students or teachers. Rather, a list of publications appears in the bibliography. Any of these titles would suffice as a general text or reference source for additional reading or research.

The total instructional time for teaching this unit of instruction as presented, is approximately 35 hours. This time-frame will, of necessity alter from one classroom teaching situation to another.

It is hoped that the material presented will provide a starting point for both students and teachers to investigate the area of wind energy conversion systems.

Dr. Martin Greenwald
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UNIT OVERVIEW

Wind Energy Conversion Systems

MAJOR CONCEPT	OVERVIEW
1.0 Historical Analysis of Wind Energy Suggested Instructional Time--2 hours	Uses of wind energy are surveyed historically, from ancient Persia, throughout the middle ages, to 19th and 20th century applications. The 20th century is examined in some detail since during this time the use of wind to produce electricity became a reality in addition to purely mechanical devices associated with wind energy in this century.
2.0 Basic Theory Suggested Instructional Time--5 hours	Theoretical considerations basic to an understanding of wind energy systems are examined, including: basic electrical theory related to generators and alternators; wind energy theory including aerodynamics, power calculations and efficiency calculations; factors affecting transmission of power; centrifugal force, mechanical advantage and theory of safety devices.
3.0 Site Analysis Suggested Instructional Time--2 hours, 30 minutes	This concept deals with the major factor affecting wind energy systems, namely, their location. Topics to be discussed include: basic site selection and local topographical considerations; techniques of measureing wind speed and direction at a specific location and the devices available to carry these measurements out; methods and techniques of analyzing data to determine the suitability of specific locations for wind energy devices.
4.0 Machine Design Fundamentals Suggested Instructional Time--5 hours	There exist many different methods of classifying wind energy machines. Almost all of these methods rely upon some design specific to the wind device. In this section, the areas examined include: rotational axis classification; blade axis classifications; rotor configuration classification; mechanical components basic to

4.0 Machine Design Fundamentals cont'd.	most wind energy machines; and electrical components basic to most wind electric systems.
5.0 Support Structures Suggested Instructional Time--2 hours, 30 minutes	Methods of supporting wind energy machines are examined. Three broad areas of support are: towers, poles and other associated support structures such as buildings and miscellaneous methods. Safety considerations of each method, along with erection procedures and maintenance are included.
6.0 Wind Energy Utilization Suggested Instructional Time--14 hours	With advancing technology, the uses of wind generated power, whether mechanical or electrical, increase in number and complexity. It is the aim of this section of the unit of study to examine the various ways in which wind power is presently being utilized, as well as some methods not yet in use but predicted for the near future. Included are: mechanical power applications, both A.C. and D.C.; and utility interfacing procedures. Included in this section are suggestions for field trips so that students can see these various systems at work and on line.
7.0 Related Factors Suggested Instructional Time--4 hours	Helping to tie together various aspects of wind energy, this section of the curriculum examines various code requirements affecting wind systems; local, state, and electrical; cost/benefit analysis calculations and national political and legal consequences of wide-scale wind energy development.

CONCEPT OUTLINE OVERVIEW

Wind Energy Conversion Systems

MAJOR CONCEPT	TIME
1.0 HISTORICAL ANALYSIS	2 hrs
1.1 Intro. to Wind Energy	30 mins
1.1.1 Uses Throughout History	15 mins
1.1.2 Density of Application	15 mins
1.2 Ancient to 1900	45 mins
1.2.1 Ancient Uses	15 mins
1.2.2 Middle Ages	15 mins
1.2.3 19th Century Applications	15 mins
1.3 1900 to Present	45 mins
1.3.1 Early 20th Century	15 mins
1.3.2 Middle 20th Century	15 mins
1.3.3 Middle 20th Century to Present	15 mins
2.0 BASIC THEORY	5 hrs
2.1 Electrical Theory	3 hrs
2.1.1 Electricity & Magnetism	1 hr
2.1.2 Ohm's Law	30 mins
2.1.3 Energy & Power Calculations	30 mins
2.1.4 Generator Basics	30 mins
2.1.5 Alternator Basics	30 mins
2.2 Wind Energy Theory	1 hr 40 mins
2.2.1 Basic Aerodynamics	20 mins
2.2.2 Power Calculations	30 mins
2.2.3 Efficiencies	20 mins
2.3 Mechanical Conversion Basics	30 mins
2.3.1 Transmission of Power	15 mins
2.3.2 Torque/Speed Ratios	15 mins
2.4 Basic Safety	20 mins
2.4.1 Factors Affecting Centrifugal Force	20 mins

3.0	SITE ANALYSIS	2 hrs 30 mins
3.1	Site Selection	1 hr
3.1.1	Lot Size	20 mins
3.1.2	Local Topography/Natural	20 mins
3.1.3	Local Topography/Man	20 mins
3.2	Wind Measurement Techniques	1 hr 30 mins
3.2.1	Wind Speed Measurements	30 mins
3.2.2	Wind Direction	30 mins
3.2.3	Wind Rose Construction	30 mins
4.0	MACHINE DESIGN FUNDAMENTALS	5 hrs
4.1	Rotational Axis Configuration	1 hr
4.1.1	Horizontal Axis Configuration	20 mins
4.1.2	Vertical Axis Configuration	20 mins
4.1.3	Design Analysis/Computations	20 mins
4.2	Blade Orientation Classification	1 hr
4.2.1	Upwind Configurations	20 mins
4.2.2	Downwind Configurations	20 mins
4.2.3	Comparative Analysis	20 mins
4.3	Rotor Configuration Classifications	1 hr
4.3.1	Blade Number	10 mins
4.3.2	Blade Design/Airfoil	10 mins
4.3.3	Torque/Speed Classifications	10 mins
4.3.4	Comparative Analysis	30 mins
4.4	Integral Mechanical Components	1 hr
4.4.1	Power Transmission Systems	15 mins
4.4.2	Overspeed Controls/Mechanical	15 mins
4.4.3	Bearings/Assorted	15 mins
4.4.4	Cables & Fasteners	15 mins
4.5	Integral Electrical Components	1 hr
4.5.1	Generators	15 mins
4.5.2	Alternators	15 mins
4.5.3	Power Control Panels	20 mins
4.5.4	Electrical Overspeed Controls	10 mins
5.0	SUPPORT STRUCTURES	2 hrs 30 mins
5.1	Towers	1 hr 30 mins
5.1.1	Open Truss Designs	15 mins

5.1.2	Guyed Structures	15 mins
5.1.3	Self-Supporting Structures	15 mins
5.1.4	Leg Number Classification	15 mins
5.1.5	Materials of Construction	30 mins
5.2	Poles	30 mins
5.2.1	Design Basics	15 mins
5.2.2	Materials for Construction	15 mins
5.3	Other Support Structures	15 mins
5.3.1	Buildings	15 mins
5.4	Basic Safety Considerations	15 mins
5.4.1	Personal Safety	15 mins
6.0	WIND ENERGY UTILIZATION	14 hrs
6.1	Mechanical Power Applications	1 hr
6.1.1	Grinding	15 mins
6.1.2	Pumping	15 mins
6.1.3	Lifting	15 mins
6.1.4	Heating	15 mins
6.2	Electrical Applications/D.C.	2 hrs.
6.2.1	Chemical Storage/Battery	30 mins
6.2.2	Resistive Loads	30 mins
6.2.3	Thermal Storage	15 mins
6.2.4	Kinetic Storage	15 mins
6.2.5	Electrolysis	15 mins
6.2.6	Standby for Inversion	15 mins
6.3	Electrical Applications/A.C.	30 mins
6.3.1	Inductive Loads	10 mins
6.3.2	Thermal Storage	10 mins
6.3.3	Line Synchronized Alternators	10 mins
6.4	Utility Interfacing Procedures	1 hr 30 mins
6.4.1	Theory of Interfacing	15 mins
6.4.2	Line Commutated Inverters	30 mins
6.4.3	Safety Aspects	15 mins
6.4.4	Legal Aspects	15 mins
6.4.5	Present-Day Assessment	15 mins
6.5	Field Trip Integration	9 hrs
6.5.1	Large Scale Electric	3 hrs
6.5.2	Small Scale Electric	3 hrs
6.5.3	Small Scale Mechanical	3 hrs

7.0	RELATED FACTORS	4 hrs
7.1	Code Requirements	2 hrs 15 mins
7.1.1	Electrical Code/NFPA	1 hr
7.1.2	Building/State and Local	45 mins
7.1.3	Zoning/Variances/Local	15 mins
7.1.4	Insurance/Permits	15 mins
7.2	Cost/Benefit Analysis	1 hr 15 mins
7.2.1	Utility Costs/Life Cycle	20 mins
7.2.2	Machine Amortizations	20 mins
7.2.3	Maintenance Costs	20 mins
7.2.4	Tax Incentives	15 mins
7.3	National, Political and Legal	30 mins
7.3.1	Topical-Current	30 mins

Total Instructional Time-35 hours

CONCEPT 1.0

HISTORICAL ANALYSIS

MAJOR CONCEPT 1.0 - HISTORICAL ANALYSIS

EDUCATIONAL OBJECTIVES

The following objectives provide the teacher with an overview of the concepts and skills contained in this section.

The student will be able to:

1.1.1.1 describe the evolution of wind power on a general basis throughout recorded history.

1.1.1.2 develop an appreciation of how wind energy has been a useful tool for mankind through recorded history.

1.1.2.1 identify the geographical distribution of wind energy utilization.

1.1.2.2 develop an appreciation of the contributions of geographic areas to the development and use of wind energy.

1.2.1.1 summarize man's early implementation of wind energy technologies.

1.2.2.1 chart the progress of wind technology during the middle ages.

1.2.3.1 correlate the use of wind energy to the industrialization of society.

1.3.1.1 trace the emergence of wind energy for generation of electricity during the early 20th century up to 1925.

1.3.2.1 classify and explain both small and large scale applications of wind energy for electrical generation.

1.3.3.1 analyze and reconstruct the rise, fall and subsequent rebirth of wind-powered electrical generators.

1.3.3.2 list two reasons for renewed interest in wind energy conversion systems.

MAJOR CONCEPT 1.0 HISTORICAL ANALYSIS **TIME** 15 mins.

1.1 Introduction to Wind Energy

1.1.1 Uses Throughout History

OBJECTIVES	STRATEGIES
1.1.1.1 describe the evolution of wind power on a general basis throughout recorded history.	a. Brainstorm with class possible uses for wind energy throughout recorded history.
1.1.1.2 develop an appreciation of how wind energy has been a useful tool for mankind through recorded history.	b. Develop a work sheet with small pictures of different types of windmills and sailing ships on a time line. Students can fill in appropriate dates and identify the task performed via wind energy.
	c. Develop and present an overhead transparency depicting historical time line.*

NOTES:

*Noyes Data Corporation: Wind Power, source for historical time chart. See also Frank Eldridge, Wind Machines and Volta Torrey, Wind-Catchers.

MAJOR CONCEPT 1.0 HISTORICAL ANALYSIS **TIME** 15 mins.

1.1 Introduction to Wind Energy

1.1.2 Density of Application

OBJECTIVES	STRATEGIES
1.1.2.1 identify the geographical distribution of wind energy utilization. 1.1.2.2 develop an appreciation of the contributions of geographic areas to the development and use of wind energy.	a. Present a slide series showing areas of the world that rely heavily on wind energy. b. Develop work sheet(s)* using a world map. Students will indicate wind energy usage in different areas of the world by using magic markers. c. Prepare an illustrated lecture on availability of wind energy. Transparency #1 & 2. d. Devise a work sheet with columns showing country and century. Students will indicate the amount of the contribution toward wind energy usage by using different colors.

NOTES:
*These work sheets need to be developed; standard overhead transparencies from a world atlas might be used.

MAJOR CONCEPT 1.0 HISTORICAL ANALYSIS **TIME** 15 mins.

1.2 Ancient to 1900

1.2.1 Ancient Uses

OBJECTIVES	STRATEGIES
1.2.1.1 summarize man's early implementation of wind energy technologies.	a. Illustrated lecture on early sailing ships and wind mills.* Transparency #3. b. Distribute hand-out with simple illustrations showing how early grinding, water pumping and lifting was accomplished using wind power energy.

NOTES:

*Palmer C. Putman, Power from the Wind.

MAJOR CONCEPT 1.0 HISTORICAL ANALYSIS **TIME** 15 mins.

1.2 Ancient to 1900

1.2.2 Middle Ages

OBJECTIVES	STRATEGIES
1.2.2.1 chart the progress of wind technology during the middle ages.	a. Develop slide series showing wind technology during the middle ages. b. Develop hand-out with the biggest and most advanced windmills of the middle ages. c. Develop a time line of significant events from ancient to present usage on a single sheet* (e.g. most significant events; also, perhaps a crossword puzzle to evaluate time line!).

NOTES:

*Time line graphs and charts are available from the American Wind Energy Association.

Poster from AWEA conference in 1977.

MAJOR CONCEPT 1.0 HISTORICAL ANALYSIS **TIME** 15 mins.

1.2 Ancient to 1900

1.2.3 19th Century Applications

OBJECTIVES	STRATEGIES
1.2.3.1 correlate the use of wind energy to the industrialization of society.	a. Develop and present a work sheet comparing the time used to complete a task by hand or with animals in contrast to windmill. b. Lecture on sailing ships, distance traveled and relationship between growth of sailing ships and world colonization. c. Show overhead transparency on sailing ships and how they move.

NOTES:

MAJOR CONCEPT 1.0 HISTORICAL ANALYSIS **TIME** 15 mins.

1.3 1900 to Present

1.3.1 Early 20th Century

OBJECTIVES	STRATEGIES
1.3.1.1 trace the emergence of wind energy for generation of electricity during the early 20th century up to 1925.	a. Present a slide series showing the development of wind energy for generating electrical power. b. Develop a work sheet or overhead transparency with small illustrations of different generators on a time line. Students will add dates.

NOTES:

MAJOR CONCEPT 1.0 Historical Analysis **TIME** 15 mins.

1.3 1900 to Present

1.3.2 Middle 20th Century

OBJECTIVES	STRATEGIES
1.3.2.1 classify and explain both small and large scale applications of wind energy for electrical generation.	a. Show slide series depicting large and small scale wind-powered electric generators. See transparency #4. b. Develop a hand out or use overhead transparency which details the components and operation of a typical large and small wind-powered generator. See transparency #5. c. Have students look up magazine articles in Reader's Guide to Periodical Literature. Make a list of all the articles. Assign the articles for which students have access to the magazines and have students write a summary of each. d. Buy or construct models of large and small wind-powered electrical generators.*

NOTES:

*For plans see Industrial Arts Manual to the Construction of Miniaturized Alternate Energy Source Equipment available from Energy Management Center, P.O. Box 190, Pasco County, Port Richey, FL 33568.

MAJOR CONCEPT 1.0 HISTORICAL ANALYSIS **TIME** 15 mins.

1.3 1900 to Present

1.3.3 Middle 20th Century to Present

OBJECTIVES	STRATEGIES
1.3.3.1 analyze and reconstruct the rise, fall and subsequent rebirth of wind-powered electrical generators. 1.3.3.2 list two reasons for renewed interest in wind energy conversion systems.	a. Discuss the use of electricity in the United States prior to the Rural Electrification Act.* b. Discuss the emerging use of wind-powered electric generators for supplying electrical power primarily in rural applications and in cathodic protection systems. c. Discuss impact of Rural Electrification Act on wind/electric industry 1940-1950. d. Have students develop line graph showing use of wind-powered electrical generators from approximately 1930-1950.** e. Discuss advantages/disadvantages of electricity generated by wind energy.

NOTES:

*Discussion should include use of other small scale electrical generating systems such as gasoline and diesel engines.

**Henry Clews, Electric Power from the Wind.

CONCEPT 2.0

BASIC THEORY

MAJOR CONCEPT 2.0 - BASIC THEORY

EDUCATIONAL OBJECTIVES

The following objectives provide the teacher with an overview of the concepts and skills contained in this section.

The student will be able to:

2.1.1.1 diagram a magnetic field and explain the theory of magnetism.

2.1.1.2 demonstrate the correlation between electricity and magnetism.

2.1.2.1 apply Ohm's law to solve simple circuit current calculations.

2.1.3.1 distinguish the difference between energy and power.

2.1.3.2 compute basic energy and power calculations.

2.1.4.1 identify the basic components of a D.C. generator and explain the function of each.

2.1.5.1 identify the basic parts of an A.C. alternator and explain the function of each.

2.2.1.1 describe the forces acting on an airfoil.

2.2.2.1 develop an appreciation of the principles governing wind power.

2.2.2.2 calculate power based on a variety of system variables.

2.2.3.1 define and give examples of energy efficiency.

2.2.3.2 identify specific concepts of efficiency related to wind system design.

2.3.1.1 identify five basic methods of transmitting power.

2.3.2.1 distinguish between torque and power and relationship to energy transmission systems.

2.4.1.1 describe centrifugal force and its affect on wind system components.

2.4.1.2 describe and draw two basic methods of preventing excessive amounts of centrifugal force in wind energy systems.

MAJOR CONCEPT 2.0 BASIC THEORY TIME 1 hour

2.1 Electrical Theory

2.1.1 Electricity and Magnetism

OBJECTIVES	STRATEGIES
2.1.1.1 diagram a magnetic field and explain the theory of magnetism. 2.1.1.2 demonstrate the correlation between electricity and magnetism.	a. Demonstrate the production of static electricity using a Van de Graaf generator. b. Demonstrate lines of force using iron filings over a sheet of cardboard covering a magnet. c. Record lines of force using wax paper and iron filings by heating wax paper with a bulb. See caution below. d. Build a simple electric circuit for demonstrations** using a bulb, power source, and battery. e. Build a lemon battery using 2 types of wire (Cu & Zn) and a galvanometer to measure current flow. f. Illustrated lecture on basic theory of magnetism and electricity.**

NOTES:

*Caution, keep heat to a minimum--a 60 watt lamp is recommended.

**Magnetism and Electricity Transparency masters are published by Milliken Publishing Company, St. Louis, Mo.

John Titterling, Electricity-Basic Electrical Concepts (Transparencies.)

MAJOR CONCEPT 2.0 BASIC THEORY **TIME** 30 mins.

2.1 Electrical Theory

2.1.2 Ohm's Law

OBJECTIVES	STRATEGIES
2.1.2.1 apply Ohm's law to solve simple circuit current calculations.	a. Illustrated lecture on Ohm's Law using analogy of water as current flow, water pressure as voltage and length/diameter of hose as resistance. b. Work sheet and/or overhead transparency with formula and problems related to voltage, amperage and ohms. c. Construct and demonstrate the use of a simple electrical circuit board (low voltage D.C.) on which voltage, current and resistance can be varied and measured.

NOTES:

MAJOR CONCEPT 2.0 BASIC THEORY **TIME** 30 mins.

2.1 Electrical Theory

2.1.3 Energy & Power Calculations

OBJECTIVES	STRATEGIES
2.1.3.1 distinguish the difference between energy and power. 2.1.3.2 compute basic energy and power calculations.	a. Show overhead transparency with definition of power and energy. Transparency #6. b. Show power panel with a simple volt and amp meter and lamp socket. Screw different wattage bulb into socket to show how higher wattage bulbs require more current. Measure voltage and current, and use power formula. c. Demonstrate large model of KWH meter (Welsch Scientific or Simpson) or show Transparency #7. d. Hand out work sheet for KWH meter for students to complete. e. Have students bring to class electrical bills and use them to determine average cost per kilowatt-hours f. Develop work sheet for determining cost for using different household appliances.

NOTES:

Contact local utility system for literature or handouts related to reading meters and determining power usage.

MAJOR CONCEPT 2.0 BASIC THEORY **TIME** 30 mins.

2.1 Electrical Theory

2.1.4 Generator Basics

OBJECTIVES	STRATEGIES
2.1.4.1 identify the basic components of a D.C. generator and explain the function of each.	a. Develop a handout sheet showing the basic parts of a D.C. generator or use Transparency #8. b. Relate the parts of a D.C. generator to a slot car motor or bicycle generator. c. Disassemble and reassemble an old D.C. automobile generator. Identify parts and explain function of same. Emphasize three basics of magnetic field, relative motion, and a conductor.

NOTES:

MAJOR CONCEPT 2.0 BASIC THEORY **TIME** 30 mins.

2.1 Electrical Theory

2.1.5 Alternator Basics

OBJECTIVES	STRATEGIES
2.1.5.1 identify the basic parts of an A.C. alternator and explain the function of each.	a. Develop a handout sheet showing basic parts of an alternator or use Transparency #9. b. Demonstrate mounting an alternator on a bicycle and load the alternator. c. Take apart an alternator. Name and show the parts and describe their operation. Have student reassamble and test the alternator.

NOTES:

MAJOR CONCEPT 2.0 BASIC THEORY **TIME** 20 mins.

2.2 Wind Energy Theory

2.2.1 Basic Aerodynamics

OBJECTIVES	STRATEGIES
2.2.1.1 describe the forces acting on an airfoil.	a. Illustrated lecture on lift/drag forces affecting an air foil. Transparency #10. b. Blow air over a thin piece of paper; ask students why paper rises. c. Have student build an airfoil or paper airplane.* d. Run a contest to determine longest flight of a paper airplane of student design.*

NOTES:

*See J. Mander, et. al, The Great International Paper Airplane Book.

MAJOR CONCEPT 2.0 BAISC THEORY **TIME** 30 mins.

2.2 Wind Energy Theory

2.2.2 Power Calculations

OBJECTIVES	STRATEGIES
2.2.2.1 develop an appreciation of the principles governing wind power. 2.2.2.2 calculate power based on a variety of system variables.	a. Discuss the law of cubes and the implication for extracting power from wind machines including theoretical maximum efficiency (59.3%). b. Illustrated lecture/discussion relating power output to wind speed and blade diameter. Transparency #11. c. Demonstrate variable output of a bicycle generator by mounting several different blades on the generator. Turn blades with a window fan.* d. Mount several different blades on a bearing supported shaft capable of rotating. Turn blades with fan and measure speed with a strobe light.* Use a wind guage to measure wind speed. Calculate tip speed and tip speed ratio. e. Develop handout sheet with problems on cube and square laws.

NOTES:

*Caution: Avoid high speeds which may create destructive centrifugal forces. If in doubt, construct shield for propeller. Demonstrator and observers should wear eye/face protection.

Jack Park, Simplified Wind Power Systems for Experimenters.

MAJOR CONCEPT 2.0 BASIC THEORY **TIME** 20 mins.

2.2 Wind Energy Theory

2.2.3 Efficiencies

OBJECTIVES	STRATEGIES
2.2.3.1 define and give examples of energy efficiency.	a. Discuss theoretical maximum efficiency of wind machines (BETZ Formula).
2.2.3.2 identify specific concepts of efficiency related to wind system design.	b. Construct models showing different blade pitch angles and size to accommodate different wind speeds.* Also, see Transparency #12 and 13.
	c. Manually spin a model of an unbalanced blade assembly.
	d. Discuss the basic formula for determining efficiency of any energy system. Transparency #14.

NOTES:

*Jack Park ., Simplified Wind Power Systems for Experimenters.

MAJOR CONCEPT 2.0 BASIC THEORY **TIME** 15 mins.

2.3 Mechanical Conversion Basics

2.3.1 Transmission of Power

OBJECTIVES	STRATEGIES
2.3.1.1 identify five basic methods of transmitting power.	a. Illustrated lecture on models of spur gear, helical gear, spiral bevel gear, plain bevel gear, hypoid gear, chains, belt, and power transmitting systems. Transparency #15 & #16. b. Film strip of automotive automatic transmission. c. Have students suggest acceptable methods for transmitting power that they are familiar with. List on chalkboard.

NOTES:

MAJOR CONCEPT 2.0 BASIC THEORY **TIME** 15 mins.

2.3 Mechanical Conversion Basics

2.3.2 Torque/Speed Rations

OBJECTIVES	**STRATEGIES**
2.3.2.1 distinguish between torque and power and relationship to energy transmission systems.	a. Illustrated lecture on relationship between speed, torque and power. b. Have student stop the drum of a small music box. c. Have a student jack up a car using a bumper jack with a short handle, then with a long handle.* d. Have one student tighten a large nut with a wrench and another student tighten the same size nut with a breaker bar for added leverage. Measure torque required to loosen with torque wrench. e. Demonstrate the operation of a ten-speed bicycle for changing torque and speed relationships.

NOTES:

*Observe strict safety precautions; use tire chocks, jack stands and adequate supervision.

MAJOR CONCEPT 2.0 BASIC THEORY **TIME** 20 mins.

2.4 Basic Safety

2.4.1 Factors Affecting Centrifugal Force

OBJECTIVES	STRATEGIES
2.4.1.1 describe centrifugal force and its affect on wind system components. 2.4.1.2 describe and draw two basic methods of preventing excessive amounts of centrifugal force in wind energy systems.	a. Discuss with class what centrifugal force is and how it can become a dangerous factor in wind system operation. b. Demonstrate centrifugal force by rotating a small can of water on a rope.* c. Illustrated lecture on methods used to govern blade speed, e.g. Flyball governors, centrifugal governors, tail vail/blade feathering. Transparency #17.

NOTES:

*Observe safety precautions and clearance during this demonstration.

CONCEPT 3.0

SITE ANALYSIS

MAJOR CONCEPT 3.0 - SITE ANALYSIS

EDUCATIONAL OBJECTIVES

The following objectives provide the teacher with an overview of the concepts and skills contained in this section.

The student will be able to:

3.1.1.1 determine minimum lot sizes for wind system implementation.

3.1.1.2 determine proper location for wind systems based on available area.

3.1.2.1 identify several natural factors of local topography that can affect wind machine performance.

3.1.3.1 identify several man-made topographical factors that can affect wind machine performance.

3.2.1.1 identify several different methods of measuring wind speed.

3.2.2.1 identify two different methods of measuring wind direction.

3.2.3.1 read and interpret a wind rose.

3.2.3.2 gather appropriate data and construct a wind rose.

MAJOR CONCEPT 3.0 SITE ANALYSIS **TIME** 20 mins.

3.1 Site Selection

3.1.1 Lot Size

OBJECTIVES	STRATEGIES
3.1.1.1 determine minimum lot sizes for wind system implementation. 2.1.1.2 determine proper location for wind systems based on available area.	a. Discuss lot sizes for residential size wind machines. Include discussion on height of tower and local zoning considerations such as height and set back restrictions. b. Have a student consult building inspector regarding the above factors.

NOTES:

MAJOR CONCEPT 3.0 SITE ANALYSIS **TIME** 20 mins.

3.1 Site Selection

3.1.2 Local Topography/Natural

OBJECTIVES	STRATEGIES
3.1.2.1 identify several natural factors of local topography that can affect wind machine performance.	a. Brainstorm with students the topographical factors (trees, mountains, valleys, water) which affect wind speed/direction. Transparency #18. b. Discuss the best location for tower location considering wind flow and foundation stability. Transparency #19.

NOTES:

MAJOR CONCEPT 3.0 SITE ANALYSIS **TIME** 20 mins.

3.1 Site Selection

3.1.3 Local Topography/Man

OBJECTIVES	STRATEGIES
3.1.3.1 Identify several man-made topographical factors that can affect wind machine performance.	a. Discuss man-made topographical factors which may affect wind machine performance. (bridges, buildings, other towers) b. Discuss general rules governing tower installation including height above existing obstructions* and distance from residence.

NOTES:

*20' above any obstruction within 500' of tower location.

MAJOR CONCEPT 3.0 SITE ANALYSIS **TIME** 30 mins.

3.2 Wind Measurement Techniques

3.2.1 Wind Speed Measurement

OBJECTIVES	STRATEGIES
3.2.1.1 identify several different methods of measuring wind speed.	a. Discuss biological wind speed indicators, including use of Beaufort Scale. Transparency #20 b. Students can gather and compile local wind speed measurements (local airport or weather bureau) over a 1-10 year period. c. Students can begin compiling local windspeed data by actual observation and measurement.*

NOTES:
*The follwoing devices could be used: Beaufort Scale, hand-held anemometer, chart recorder, battery-operated anemometer, self-made anemometer.

MAJOR CONCEPT 3.0 SITE ANALYSIS **TIME** 30 mins.

3.2 Wind Measurement Techniques

3.2.2 Wind Direction Measurement Instruments

OBJECTIVES	STRATEGIES
3.2.2.1 identify two different methods of measuring wind direction.	a. Discuss methods used to measure wind direction relative to compass bearings. b. Students can gather wind direction data from local airport or weather station. c. Students can compile a record of wind direction data by observing and recording with a hand-held wind direction indicator.

NOTES:

MAJOR CONCEPT 3.0 SITE ANALYSIS **TIME** 30 mins.

3.2 Wind Measurement Techniques

3.2.3 Wind Rose Construction

OBJECTIVES	STRATEGIES
3.2.3.1 Read and interpret a wind rose.	a. Discuss with students the procedures for interpreting a wind rose. Transparency #21.
3.2.3.2 Gather appropriate data and construct a wind rose.	b. Using available data, construct a wind rose in class.*

NOTES:

*Frank Eldridge , Wind Machines, 1980

CONCEPT 4.0

MACHINE DESIGN

MAJOR CONCEPT 4.0 - MACHINE DESIGN FUNDAMENTALS

EDUCATIONAL OBJECTIVES

The following objectives provide the teacher with an overview of the concepts and skills contained in this section.

The student will be able to:

4.1.1.1 identify and describe horizontal axis wind machines.

4.1.2.1 identify and describe vertical axis wind machines.

4.1.3.1 identify advantages and disadvantages of each axis classification.

4.2.1.1 identify and describe upwind generator systems.

4.2.2.1 identify and describe downwind systems.

4.2.3.1 identify the advantages and disadvantages of each wind/orientation classification.

4.3.1.1 identify wind generator systems by blade numbers.

4.3.1.2 enumerate the advantages and disadvantages of various blade number configurations.

4.3.2.1 distinguish and evaluate blade performance of various airfoil configurations.

4.3.3.1 estimate optimum rotor rpm for each type of wind machine application.

4.3.4.1 analyze known rotor and blade characteristics in relation to end use strategy.

4.4.1.1 identify several methods for transmitting rotational power.

4.4.2.1 identify four mechanical methods for controlling overspeed conditions of wind rotors.

4.4.3.1 distinguish between various bearing systems and devices for reducing friction.

4.4.4.1 identify basic mechanical cable classifications and associated hardware.

4.5.1.1 disassemble, identify parts and reassemble a working D.C. generator.

4.5.2.1 disassemble, identify parts and reassemble a working alternator.

4.5.3.1 identify and evaluate the components in a "typical" residential wind electric control panel.

4.5.4.1 identify and evaluate major electrical systems for controlling overspeeding.

MAJOR CONCEPT 4.0 MACHINE DESIGN FUNDAMENTALS **TIME** 20 mins.

4.1 Rotational Axis Classifications

4.1.1 Horizontal Axis Configurations

OBJECTIVES	STRATEGIES
4.1.1.1 Identify and describe horizontal axis wind machines.	a. Lecture with overhead transparencies showing various horizontal axis classifications.* Transparency #22 and 22A. b. Slide/lecture series depicting horizontal axis designs. c. Model building-tail vane apparatus with small fan to show tail vane orientation. d. Field trip showing one or more various horizontal axis machines in use.*

NOTES:

*See Montclair State College/Ramapo College of New Jersey/Trenton State College for operating wind systems. Consult with Northeast Solar Energy Center, Cambridge, Mass. regarding wind energy conversion systems in New Jersey or contact N.J. Department of Energy Hot Line, #800-492-4242, Newark, N.J.

MAJOR CONCEPT 4.0 MACHINE DESIGN FUNDAMENTALS **TIME** 20 mins.

4.1 Rotational Axis Classifications

4.1.2 Vertical Axis Configurations

OBJECTIVES	STRATEGIES
4.1.2.1 Identify and describe vertical axis wind machines.	a. Lecture with overhead transparencies showing various vertical axis classifications. Transparency #22 & 22A. b. Slide/lecture series depicting vertical axis classifications. c. Model building-Savonius rotors with tin cans showing omnidirectional ability of Savonius. d. Field trip showing one or more vertical axis designs.

NOTES:

MAJOR CONCEPT 4.0 MACHINE DESIGN FUNDAMENTALS **TIME** 20 mins.

4.1 Rotational Axis Configurations

4.1.3 Design Analysis/Comparison

OBJECTIVES	STRATEGIES
4.1.3.1 Identify advantages and disadvantages of each axis classification.	a. Class discussion of advantages of each type of axis classification. b. Gathering of industry information pamphlets describing features of each machine.* c. Independent study to build model of either horizontal or vertical axis unit of student choice. d. Bulletin board display of both types of axis rotations.

NOTES:

*See Winter, 1979 issue of Wind Power Digest for full manufacturers access listing.

MAJOR CONCEPT 4.0 MACHINE DESIGN FUNDAMENTALS **TIME** 20 mins.

4.2 Blade Orientation Classification

4.2.1 Upwind Configurations

OBJECTIVES	STRATEGIES
4.2.1.1 Identify and describe upwind generator systems.	a. Lecture discussion with transparencies depicting upwind blade orientation. Transparencies #22 and 22A. b. Slide/discussion depicting upwinding blade orientation. c. Show blade orientation with small fan and model. d. Independent study: model building of upwind blade design.*

NOTES:

*Jack Park, Simplified Wind Power System for Experimenters.

MAJOR CONCEPT 4.0 MACHINE DESIGN FUNDAMENTALS **TIME** 20 mins.

4.2 Blade Orientation Classification

4.2.2 Downwind Configurations

OBJECTIVES	STRATEGIES
4.2.2.1 Identify and describe downwind generator system.	a. Lecture/discussion with transparencies for downwind configurations.* Transparencies #22 and 22A. b. Slide/discussion with slides for depicting downwind configurations. c. Blade orientation demonstration with model and fan. d. Independent Study: model building of downwind blade design.

NOTES:

*Spring, 1980 issue of Wind Power Digest.

MAJOR CONCEPT 4.0 MACHINE DESIGN FUNDAMENTALS **TIME** 20 mins.

4.2 Blade Orientation Classification

4.2.3 Comparative Analysis

OBJECTIVES	STRATEGIES
4.2.3.1 Identify the advantages and disadvantages of each wind/orientation classification.	a. Class discussion of relative advantages of each type of blade orientation. b. Gathering of industrial information about upwind and downwind systems. c. Make a bulletin board display of each type of orientation system.

NOTES:

MAJOR CONCEPT 4.0 MACHINE DESIGN FUNDAMENTALS **TIME** 10 mins.

4.3 Rotor Configuration Classification

4.3.1 Blade Number

OBJECTIVES	STRATEGIES
4.3.1.1 Identify wind generator systems by blade numbers. 4.3.1.2 Enumerate the advantages and disadvantages of various blade number configurations.	a. Class discussion focusing on variety of different numbers of blades used on systems. Transparencies #22 and 22A. b. Show transparencies and/or slides of each of a variety of machines at different blade numbers.* c. Discussion of advantages and disadvantages of blade numbers relative to balancing of machine.

NOTES:

*Palmer Putnam, Power from the Wind.

MAJOR CONCEPT 4.0 MACHINE DESIGN FUNDAMENTALS **TIME** 10 mins.

4.3 Rotor Configuration Classifications

4.3.2 Blade Design/Airfoils

OBJECTIVES	STRATEGIES
4.3.2.1 Distinguish and evaluate blade performance of various airfoil configurations.	a. Lecture with transparencies showing basic blade design and airfoil shapes.* Transparency #23.

NOTES:

*See Park, J., Simplified Wind Power Systems for Experimenters.

MAJOR CONCEPT 4.0 MACHINE DESIGN FUNDAMENTALS **TIME** 10 mins.

4.3 Rotor Configuration Classifications

4.3.3 Torque/Speed Classifications

OBJECTIVES	STRATEGIES
4.3.3.1 Estimate optimum rotor rpm for each type of wind machine application.	a. Class discussion/lecture focusing on generator rpm versus rotor rpm. b. Charts/slides/transparencies depicting methods of increasing generator speed vs. rotor speed. c. Discussion dealing with speeds for mechanical versus electrical applications.

NOTES:

MAJOR CONCEPT 4.0 MACHINE DESIGN FUNDAMENTALS **TIME** 30 mins.

4.3 Rotor Configuration Classification

4.3.4 Comparative Analysis

OBJECTIVES	STRATEGIES
4.3.4.1 Analyze known rotor and blade characteristics in relation to end use strategy.	a. Class discussion of different airfoil shapes. b. Design contest: students build blade sections and mount on bearing to see which turns best (fastest) at slowest level speed using a fan.* c. Independent study project: prepare model cross sections of various airfoil shapes for display board.

NOTES:
*Observe adequate safety precautions during rotation test.

MAJOR CONCEPT 4.0 MACHINE DESIGN FUNDAMENTALS **TIME** 15 mins.

4.4 Integral Mechanical Components

4.4.1 Power Transmission Systems

OBJECTIVES	STRATEGIES
4.4.1.1 Identify several methods for transmitting rotational power.	a. Class lecture utilizing models showing gears, belts, pulleys, chains and sprokets.* b. Demonstrate common examples of transmission systems in use (stereo turntables, car generators, etc.). c. Demonstration of mechanical advantages utilizing pulleys to pick up tremendous weights at reduced effort. d. Explanation of power transmission systems demonstrating the automobile standard transmission.

NOTES:

*Consult media available on auto power systems (alternator belts, etc.).

MAJOR CONCEPT 4.0 MACHINE DESIGN FUNDAMENTALS **TIME** 15 mins.

4.4 Integral Mechanical Components

4.4.2 Overspeed Controls/Mechanical

OBJECTIVES	STRATEGIES
4.4.2.1 Identify four mechanical methods for controlling overspeed conditions of wind rotors.	a. Class discussion using charts to identify flyball governors and how they work.* Transparencies #24, 24A. b. Use chart or overhead transparency to identify how air brakes control overspreading.** c. Independent study: build scale model of air brake or centrifugal governor. d. Using charts, identify operation of blade activated centrigural governors.*

NOTES:

*Jacobs Wind Electric Manual, Northwind Power Comapny.
**Windchanger Manual, Dyna Technology, Inc.

MAJOR CONCEPT 4.0 MACHINE DESIGN FUNDAMENTALS **TIME** 15 mins.

4.4 Integral Mechanical Components

4.4.3 Bearings/Assorted

OBJECTIVES	STRATEGIES
4.4.3.1 Distinguish between various bearing systems and devices for reducing friction.	a. Class discussion: identify three classifications of friction--dry, greasy, viscuous. b. Display various types of bearings commonly found such as roller, ball, tapered roller, etc.

NOTES:

MAJOR CONCEPT 4.0 MACHINE DESIGN FUNDAMENTALS **TIME** 15 mins.

4.4 Integral Mechanical Components

4.4.4 Cables & Fasteners

OBJECTIVES	STRATEGIES
4.4.4.1 Identify basic mechanical cable classifications and associated hardware.	a. Prepare demonstration of basic cable types; solid steel; braided; galvanized. b. Class discussion of cable thickness vs. strength. c. Demonstration of tensile test on cable for breaking strength--use tensile tester.*

NOTES:

* Adequate safety precautions should be employed when using tensile tester.

MAJOR CONCEPT 4.0 MACHINE DESIGN FUNDAMENTALS **TIME** 15 mins

4.5 Integral Electrical Components

4.51 Generators

OBJECTIVES	STRATEGIES
4.5.1.1 Disassemble, identify parts and reassemble a working D.C. generator.	a. Discuss with students the major parts of a D.C. generator and how it functions. Transparency #25. b. Working individually or in groups, students will disassemble, identify parts; and reassemble a working generator.* c. Set up demonstration stand with motor, generator, voltmeter and variable speed control to regulate output.* d. Lecture on auto electrical system with D.C. generator and voltage regulation.

NOTES:

*Observe adequate safety precautions related to hand tool use, rotating mechanisms, and electrical safety.

MAJOR CONCEPT 4.0 MACHINE DESIGN FUNDAMENTALS **TIME** 15 mins.

4.5 Integral Electrical Components

4.5.2 Alternators

OBJECTIVES	STRATEGIES
4.5.2.1 Disassemble, identify parts and reassemble a working alternator.	a. Display a working alternator, identifying major working components and their function. b. Working individually or in groups, students can disassemble, identify parts, and reassemble a working alternator.* c. Set up demonstration table with motor and alternator and variable speed control to vary electrical output.* d. Lecture on auto electrical system with alternator and voltage regulation.

NOTES:

*Observe adequate safety precautions related to hand tool use, rotating mechanisms, and electrical safety.

MAJOR CONCEPT 4.0 MACHINE DESIGN FUNDAMENTALS **TIME** 20 mins.

4.5 Integral Electrical Components

4.5.3 Power Control Panels

OBJECTIVES	STRATEGIES
4.5.3.1 Identify and evaluate the components in a "typical" residential wind electric control panel.	a. Identify the major working components in a typical control panel.* b. Independent study: develop project for students singly or in groups to design a simple wind electric control box.

NOTES:

*Northwind Power Company. Revised Supplement to Jacobs Instruction Manual.

MAJOR CONCEPT 4.0 MACHINE DESIGN FUNDAMENTALS **TIME** 10 mins.

4.5 Integral Electrical Components

4.5.4 Electrical Overspeed Controls

OBJECTIVES	STRATEGIES
4.5.4.1 Identify and evaluate major electrical systems for controlling overspeeding.	a. Lecture explaining electrical braking mechanisms.

NOTES:

CONCEPT 5.0

SUPPORT STRUCTURES

MAJOR CONCEPT 5.0 - SUPPORT STRUCTURES

EDUCATIONAL OBJECTIVES

The following objectives provide the teacher with an overview of the concepts and skills contained in this section.

The student will be able to:

5.1.1.1 diagram and construct a one section model of an open truss design, support tower.

5.1.2.1 explain the theory of guyed support structures.

5.1.2.2 sketch various means of guying two different types of support towers.

5.1.3.1 explain the structural design characteristics of three and four post steel towers.

5.1.4.1 identify windmill towers according to the number of supporting legs and/or anchor posts.

5.1.5.1 identify several different materials used in the construction of windmill towers and the relative advantages and disadvantages of each: steel, concrete, wood.

5.2.1.1 analyze the basics of designing poles for supporting wind machines.

5.2.2.1 identify three different materials used in the construction of wind-powered electrical generator support poles and the relative advantages and disadvantages of wood, steel, or concrete poles.

5.3.1.1 describe various ways that a building can be used to support a wind-powered electric generator.

5.4.1.1 state four safety rules applicable to support towers.

MAJOR CONCEPT 5.0 SUPPORT STRUCTURES **TIME** 15 mins.

5.1 Towers

5.11 Open Truss Design

OBJECTIVES	STRATEGIES
5.1.1.1 Diagram and construct a one section model of an open truss design, support tower.	a. Illustrated lecture on open truss design.* b. Building contest: using toothpicks, have students build one foot tower, see which one supports the greatest amount of weight. Award prizes. c. Discussion of various methods of raising towers using cranes or the gin pole.

NOTES:

*See Unarco-Rohn, Peoria, Il.

MAJOR CONCEPT 5.0 SUPPORT STRUCTURES **TIME** 15 mins.

5.1 Towers

5.1.2 Guyed Structures

OBJECTIVES	STRATEGIES
5.1.2.1 Explain the theory of guyed support structures. 5.1.2.2 Sketch various means of guying two different types of support towers.	a. Use transparency to show guyed tower designs: differentiate between towers and poles.

NOTES:

Source Rohn Towers; Peoria, Il. or Enertech Corp., Norwich, Vt.

MAJOR CONCEPT 5.0 SUPPORT STRUCTURES **TIME** 15 mins.

5.1 Towers

5.1.3 Self-Supporting Structures

OBJECTIVES	STRATEGIES
5.1.3.1 Explain the structural design characteristics of three and four post steel towers.	a. Illustrated lecture on self-supporting towers with emphasis on structural members, bracing, fastening and anchoring to foundation.

NOTES:

MAJOR CONCEPT 5.0 SUPPORT STRUCTURES **TIME** 15 mins.

5.1 Towers

5.1.4 Leg Number Classification

OBJECTIVES	STRATEGIES
5.1.4.1 Identify windmill towers according to the number of supporting legs and/or anchor posts.	a. Have students develop bulletin board illustrating typical tower leg configurations. b. Illustrated lecture on tower leg configurations.

NOTES:

Support structures could be grouped together in two or three transparencies. Also, students can be broken into groups, and each group assigned to construct a particular type of tower.

MAJOR CONCEPT 5.0 SUPPORT STRUCTURES **TIME** 30 mins.

5.1 Towers

5.1.5 Materials of Construction

OBJECTIVES	STRATEGIES
5.1.5.1 Identify several different materials used in the construction of windmill towers and the relative advantages and disadvantages of each: steel, concrete, wood.	a. Class discussion focusing on relative advantages of steel, wood, or concrete for support structures. b. Class discussion on merits of galvanized steel vs. untreated steel.*

NOTES:

*See Unarco-Rohn Tower literature relating to galvanized steel (Unarco-Rohn Tower, Peoria, Il.)

MAJOR CONCEPT 5.0 SUPPORT STRUCTURES **TIME** 15 mins.

5.2 Poles

5.2.1 Design Basics

OBJECTIVES	STRATEGIES
5.2.1.1 Analyze the basics of designing poles for supporting wind machines.	a. Classroom discussion focusing on the use of poles as support structures for wind-powered electric generators.

NOTES:

*See current literature from Enertech, Inc., Norwich, Vt. and appendix of Wind Machines by Frank Eldridge.

MAJOR CONCEPT 5.0 SUPPORT STRUCTURES **TIME** 15 mins.

5.2 Poles

5.2.2 Materials for Construction

OBJECTIVES		STRATEGIES	
5.2.2.1	Identify three different materials used in the construction of wind-powered electrical generator support poles and the relative advantages and disadvantages of wood, steel, or concrete materials.	a.	Classroom discussion focusing on the use of wood, steel and concrete for constructing poles for wind generators.

NOTES:

MAJOR CONCEPT 5.0 SUPPORT STRUCTURES **TIME** 15 mins.

5.3 Other Support Structures

5.3.1 Buildings

OBJECTIVES	STRATEGIES
5.3.1.1 Describe various ways that a building can be used to support a wind-powered electric generator.	a. Classroom discussion focusing on the use of buildings for tower support.* Transparency #26.

NOTES:

*See Energy Task Force, Windmill Power.

MAJOR CONCEPT 5.0 SUPPORT STRUCTURES **TIME** 15 mins.

5.4 Basic Safety Considerations

5.4.1 Personal Safety

OBJECTIVES	STRATEGIES
5.4.1.1 State four safety rules applicable to support towers.	a. Brainstorm with class safety precautions such as hard hats, safety belts, climbing procedures and step removal.

NOTES:

CONCEPT 6.0

UTILIZATION

MAJOR CONCEPT 6.0 - WIND ENERGY UTILIZATION

EDUCATIONAL OBJECTIVES

The following objectives provide the teacher with an overview of the concepts and skills contained in this section.

The student will be able to:

6.1.1.1 diagram the uses of windmill machines for grinding applications.

6.1.2.1 describe the use of wind-powered machines for water pumping applications.

6.1.2.2 outline strategy for the limits of specific pumping applications.

6.1.3.1 describe the use of wind power for lifting and elevating applications.

6.1.4.1 describe the use of wind energy for mechanical heating systems.

6.2.1.1 distinguish between different types of chemical batteries.

6.2.1.2 illustrate the chemical conversion process used in storage batteries.

6.2.2.1 identify five types of resistive loads: e.g. light bulbs, space heaters, water heaters, toasters, batteries.

6.2.2.2 explain how and why a wind generator can directly power resistive loads.

6.2.3.1 identify and illustrate wind-powered thermal storage systems.

6.2.4.1 identify and diagram wind-powered kinetic energy storage systems: e.g. flywheels.

6.2.5.1 identify the concept of electrolysis and how wind generators can be used in this application.

6.2.5.2 outline end uses for electrolysis and how wind generators can be used in this application.

6.2.6.1 summarize the concept of power inversion and how wind-powered generators are used in this type of power system.

6.3.1.1 explain what electrical inductive loads are and cite three examples of such devices, e.g. flourescent lights, induction motors, and television sets.

6.3.1.2 detail the use of wind-powered generators for direct powering of industrial load devices.

6.3.2.1 identify various methods of thermal storage techniques applicable to the use of wind generated A.C. current such as hot water, storage heat pumps, etc.

6.3.3.1 explain the theory of alternator synchronization.

6.3.3.2 explain how wind-powered generators can be used to produce power in synchronization with utility grid systems.

6.4.1.1 explain the theory of interfacing a wind-powered generator with utility supplied electrical power.

6.4.2.1 explain and diagram the operation of a line commutated inverter.

6.4.2.2 diagram and explain the synchronous inversion of variable D.C. power to a standard 200 V, 60 cycle grid line.

6.4.3.1 detail three safety aspects to be considered when interfacing a wind-powered generator with a utility grid, e.g. power failure, isolating synchronous generation and fusing.

6.4.4.1 identify and explain legal aspects involved with the use of synchronous inverters.

6.4.5.1 assess and identify the present state of development of synchronous inversion systems with the state and predictions for future implementation.

6.5.5.1 diagram the energy flow pattern of a large scale wind system seen in a field trip and discuss the advantages and disadvantages of a large scale wind system.

6.5.2.1 diagram the energy flow pattern of a small scale wind electric system seen in a field trip and discuss the advantages and disadvantages of a small scale wind system.

6.5.3.1 diagram the energy flow and chart specific site capacities of a small scale mechanical wind energy system seen in a field trip.

MAJOR CONCEPT 6.0 WIND ENERGY UTILIZATION **TIME** 15 mins.

6.1 Mechanical Power Applications

6.1.1 Grinding

OBJECTIVES	STRATEGIES
6.1.1.1 Diagram the uses of windmill machines for grinding applications.	a. Lecture on historic use with overhead projection of grist mill (cutaway). Transparency #27. b. Dramatize (role play) parts in a miller's life. c. Homework assignment on historic application with class discussion. d. Field trip to Volendam Windmill in Milford, N.J. (Hunterdon County) a restored windmill with grinding stones. Paul Jorgensen, proprietor.

NOTES:

MAJOR CONCEPT 6.0 WIND ENERGY UTILIZATION **TIME** 15 mins.

6.1 Mechanical Power Applications

6.1.2 Pumping

OBJECTIVES	STRATEGIES
6.1.2.1 Describe the use of wind-powered machines for water pumping applications. 6.1.2.2 outline strategy for the limits of specific pumping applications.	a. Class discussion with transparency diagramming parts of wind pumping systems. Show 16 mm film "Gusts of Power," available from Department of Energy. b. Problem solving on how to raise water and how far it can be raised.* c. Discussion of different types of pumps.

NOTES:

*Sources for lifting water versus pump diameters can be found in manuals supplied by Aermotor, Dempster or Heller Aller Co. water pumping wind systems.

MAJOR CONCEPT 6.0 WIND ENERGY UTILIZATION **TIME** 15 mins.

6.1 Mechanical Power Application

6.1.3 Lifting

OBJECTIVES	STRATEGIES
6.1.3.1 Describe the use of wind power for lifting and elevating applications.	a. Demonstration and discussion of simple machines and gearing used to lift. b. Homework assignment with class discussion. c. Individual student report with question and answer period.

NOTES:

MAJOR CONCEPT 6.0 Wind Energy Utilization **TIME** 15 mins.

6.1 Mechanical Power Applications

6.1.4 Heating

OBJECTIVES	STRATEGIES
6.1.4.1 Describe the use of wind energy for mechanical heating systems.	a. Lecture on mechanics of mechanical heating through friction and gearing for wind applications. b. Demonstration of mechanical heating with model. c. Homework assignment with class discussion. d. Show film "Gusts of Power," D.O.E. e. Field trip to New York University: Lebost Turbine U.S.D.A. Barney Building: Water Heating Windmill.

NOTES:

MAJOR CONCEPT 6.0 WIND ENERGY UTILIZATION **TIME** 30 mins.

6.2 Electrical Application/D.C.

6.2.1 Chemical Storage/Battery

OBJECTIVES	STRATEGIES
6.2.1.1 Distinguish between different types of chemical batteries. 6.2.1.2 Illustrate the chemical conversion process used in storage batteries.	a. Lecture on chemical action in different batteries. b. Demonstration of chemical generation of electricity using "lemon battery." c. Have class build a dry cell battery from kit. d. Discuss and diagram with the class a complete wind electrical system installation using battery storage and D.C. wiring. Transparency #28.

NOTES:

MAJOR CONCEPT 6.0 WIND ENERGY UTILIZATION TIME 30 mins.

6.2 Electrical Application/D.C.

6.2.2 Resistive Loads

OBJECTIVES	STRATEGIES
6.2.2.1 Identify five types of resistive loads: e.g. light bulbs, space heaters, water heaters, toasters, batteries. 6.2.2.2 Explain how and why a wind generator can directly power resistive loads.	a. Homework assignment with panel discussion. Transparency #29. b. Brainstorming session on types of resistive loads. c. Class discussion of "what is a resistive load?"

NOTES:

MAJOR CONCEPT 6.0 WIND ENERGY UTILIZATION **TIME** 15 mins.

6.2 Electrical Applications/D.C.

6.2.3 Thermal Storage

OBJECTIVES	STRATEGIES
6.2.3.1 Identify and illustrate wind-powered thermal storage systems.	a. Independent study assignment-research project. b. Lecture by instructor. c. Individual class reports. d. Classroom discussion of ways to store energy (thermal). e. Show film--Gusts of Power-D.O.E.

NOTES:

MAJOR CONCEPT 6.0 WIND ENERGY UTILIZATION **TIME** 15 mins.

6.2 Electrical Application/D.C.

6.2.4 Kinetic Storage

OBJECTIVES	STRATEGIES
6.2.4.1 Identify and diagram wind-powered kinetic energy storage systems: e.g. flywheels.	a. Independent study assignment. b. Lecture by instructor and demonstration of spinning bicycle wheels and kinetic energy. c. Individual class reports.

NOTES:

MAJOR CONCEPT 6.0 Wind Energy Utilization **TIME** 15 mins.

6.2 Electrical Application/D.C.

6.2.5 Electrolysis

OBJECTIVES	STRATEGIES
6.2.5.1 Identify the concept of electrolysis and how wind generators can be used in this application. 6.2.5.2 Outline end uses for electrolysis and how wind generators can be used in this application.	a. Discussion of principles of electrolysis and electrical power needs. b. Demonstration of principles (water, etc.). c. Lab assignment--set up and operate a simple electrolysis tank.

NOTES:

MAJOR CONCEPT 6.0 WIND ENERGY UTILIZATION **TIME** 15 mins.

6.2 Electrical Applications/D.C.

6.2.6 Stand by for Inversion

OBJECTIVES	STRATEGIES
6.2.6.1 Summarize the concept of power inversion and how wind powered generators are used in this type of power system.	a. Lecture on theory of power inversion/demonstration. b. Utilizing instruction booklet from Soleq or Gemini, discuss theory of inversion.* c. Using transparencies, discuss difference between power conversion and inversion.

NOTES:

*Windworks Inc. Gemini Synchronous Inverter Systems.

MAJOR CONCEPT 6.0 WIND ENERGY UTILIZATION **TIME** 10 mins.

6.3 Electrical Applications/A.C.

6.3.1 Inductive Loads

OBJECTIVES	STRATEGIES
6.3.1.1 Explain what electrical inductive loads are and cite three examples of such devices, e.g. flourescent lights, induction motors, and television sets. 6.3.1.2 Detail the use of wind-powered generators for direct powering of industrial load devices.	a. Lecture on induction and inductive loads. b. Student report or homework assignment on induction. c. Lab work--apply current to inductive loads and measure.*

NOTES:

*Adequate safety measures shall be in effect when students work with electrical devices.

MAJOR CONCEPT 6.0 WIND ENERGY UTILIZATION **TIME** 10 mins.

6.3 Electrical Applications/A.C.

6.3.2 Thermal Storage

OBJECTIVES	STRATEGIES
6.3.2.1 Identify various methods of thermal storage techniques applicable to the use of wind generated AC current such as hot water, storage heat pumps, etc.	a. Independent study project: identify manufacturers of thermal storage energy systems suitable for wind energy applications. See Wind Energy Bibliography published by Windworks.

NOTES:

MAJOR CONCEPT 6.0 WIND ENERGY UTILIZATION **TIME** 10 mins.

6.3 Electrical Applications/A.C.

6.3.3 Line Synchronized Alternators

OBJECTIVES	STRATEGIES
6.3.3.1 Explain the theory of alternator synchronization. 6.3.3.2 Explain how wind-powered generators can be used to produce power in synchronization with utility grid systems.	a. Lecture/demonstration by instructor using information supplied by Windworks, Inc. b. Demonstration of synchronous applications.

NOTES:

MAJOR CONCEPT 6.0 WIND ENERGY UTILIZATION **TIME** 15 mins.

6.4 Utility Interfacing Procedures

6.4.1 Theory of Interfacing

OBJECTIVES	STRATEGIES
6.4.1.1 Explain the theory of interfacing a wind-powered generator with utility supplied electrical power.	a. Lecture by instructor using Gemini synchronous inverter information.

NOTES:

MAJOR CONCEPT 6.0 WIND ENERGY UTILIZATION **TIME** 30 mins.

6.4 Utility Interfacing Procedures

6.4.2 Line Commutated Inverters

OBJECTIVES	STRATEGIES
6.4.2.1 Explain and diagram the operation of a line commutated inverter. 6.4.2.2 Diagram and explain the synchronous inversion of variable D.C. power to a standard 200 V, 60 cycle grid line.	a. Lecture on line commutated inverters using information from Gemini manual.

NOTES:

MAJOR CONCEPT 6.0 WIND ENERGY UTILIZATION **TIME** 15 mins.

6.4 Utility Interfacing Procedures

6.4.3 Safety Aspects

OBJECTIVES	STRATEGIES
6.4.3.1 Detail three safety aspects to be considered when interfacing a wind-powered generator with a utility grid, e.g. power failure, isolating synchronous generation and fusing.	a. Lecture/demonstration of safety techniques for using synchronous inverters. b. Panel discussion with homework assignment: an examination of recent utility commission decisions regarding the use of wind-powered generators tied to utility grids (could also be an independent study project).

NOTES:

MAJOR CONCEPT 6.0 WIND ENERGY UTILIZATION **TIME** 15 mins.

6.4 Utility Interfacing Procedures

6.4.4 Legal Aspects

OBJECTIVES	STRATEGIES
6.4.4.1 Identify and explain legal aspects involved with the use of synchronous inverters.	a. Lecture by instructor on recent utility commission windmill/utility decisions. b. Guest speaker--legal counsel or utility representative.

NOTES:

MAJOR CONCEPT 6.0 WIND ENERGY UTILIZATION **TIME** 15 mins.

6.4 Utility Interfacing

6.4.5 Present Day Assessment

OBJECTIVES	STRATEGIES
6.4.5.1 Assess and identify the present state of development of synchronous inversion systems within NJ/NY and predictions for future implementation.	a. Homework or library assignment--determine approximate number of utility interfaced residential wind generators in New York and New Jersey.

NOTES:

MAJOR CONCEPT 6.0 WIND ENERGY UTILIZATION TIME 3 hours

6.5 Field Trip Integration

6.5.1 Large Scale Electric

OBJECTIVES	STRATEGIES
6.5.5.1 Diagram the energy flow pattern of a large scale wind system seen in a field trip and discuss the advantages and disadvantages of a large scale wind system.	a. Field trip (or slide series presentation).* b. Homework assignment--develop hand out for field trip, e.g. what you should look for. c. Classroom presentation (individual or group). d. Independent study of large scale installations.

NOTES:

*See bibliography for suggested sites.

MAJOR CONCEPT 6.0 WIND ENERGY UTILIZATION **TIME** 3 hours

6.5 Field Trip Integration

6.5.2 Small Scale Electric

OBJECTIVES	STRATEGIES
6.5.2.1 Diagram the energy flow pattern of a small scale wind electric system seen in a field trip and discuss the advantages and disadvantages of a small scale wind system.	a. Field trip (or slide series presentation).* b. Homework assignment: list of operational sites in New Jersey. c. Classroom presentation (individual or group). d. Independent study.

NOTES:

*See bibliography for suggested sites.

MAJOR CONCEPT 6.0 WIND ENERGY UTILIZATION **TIME** 3 hours

6.5 Field Trip Integration

6.5.3 Small Scale Mechanical

OBJECTIVES	STRATEGIES
6.5.3.1 Diagram the energy flow and chart specific site capacities of a small scale mechanical wind energy system seen in a field trip.	a. Field trip (or slide series presentation).* b. Homework assignment; develop list of existing sites. c. Classroom presentation (individual or group). d. Independent study.

NOTES:

*See bibliography for suggested sites.

CONCEPT 7.0

RELATED FACTORS

MAJOR CONCEPT 7.0 - RELATED FACTORS

EDUCATIONAL OBJECTIVES

The following objectives provide the teacher with an overview of the concepts and skills contained in this section.

The student will be able to:

7.1.1.1 demonstrate a familiarity with applying NFPA requirements relating to wind energy installations.

7.1.2.1 identify specific state building codes that apply to the installation of residential wind electric systems.

7.1.3.1 explain the meaning of zoning classifications and variances applied to local residential lots.

7.1.3.2 identify how appropriate procedures are undertaken to gain local permits for residential wind-powered generator installation.

7.1.4.1 identify several potential hazards to be covered by specific insurance policies applicable to residential energy systems.

7.2.1.1 using best available projections, calculate utility electrical costs over the life cycle of an installed wind energy system.

7.2.2.1 calculate the amortization of a wind electric system based on machine life cycle output.

7.2.2.2 compare utility supplied power to wind machine supplied power and determine overall cost effectiveness.

7.2.3.1 list several periodic maintenance procedures for wind systems.

7.2.3.2 produce an annual maintenance schedule with projected costs for a small residential wind energy system.

7.2.4.1 specify current applicable tax incentives related to the installation of residential wind energy system.

7.3.1.1 identify and discuss topics of current concern on either a local or national level.

MAJOR CONCEPT 7.0 RELATED FACTORS **TIME** 1 hour

7.1 Code Requirement

7.1.1 Electrical Code/NFPA

OBJECTIVES	STRATEGIES
7.1.1.1 Demonstrate a familiarity with applying NFPA requirements related to wind energy installations.	a. Guest speaker: local electrical inspector or electrician. b. Class discussions of present code requirements using NFPA code book.

NOTES:

MAJOR CONCEPT 7.0 RELATED FACTORS **TIME** 45 mins.

7.1 Code Requirements

7.1.2 Building/State and Local

OBJECTIVES	STRATEGIES
7.1.2.1 Identify specific state building codes that apply to the installation of residential wind electric systems.	a. Guest speaker: local building inspector or contractor.*

NOTES:

*Discussion of cost factors of codes in this area.

MAJOR CONCEPT 7.0 RELATED FACTORS **TIME** 15 mins.

7.1 Code Requirements

7.1.3 Zoning/Variances/Local

OBJECTIVES	STRATEGIES
7.1.3.1 Explain the meaning of zoning classifications and variances applicable to local residential lots.	a. Guest speaker: local building inspector or member of zoning board.
7.1.3.2 Identify how appropriate procedures are undertaken to gain local permits for residential wind-powered generator installation.	b. Class discussion using local building code as a basis for the discussion.

NOTES:

MAJOR CONCEPT 7.0 RELATED FACTORS **TIME** 15 mins.

7.1 Code Requirements

7.1.4 Insurance/Permits

OBJECTIVES	STRATEGIES
7.1.4.1 Identify several potential hazards to be covered by specific insurance policies applicable to residential energy systems.	a. Guest speaker: local insurance representative.

NOTES:

MAJOR CONCEPT 7.0 RELATED FACTORS **TIME** 20 mins.

7.2 Cost-Benefit Analysis

7.2.1 Utility Costs/Life Cycle

OBJECTIVES	STRATEGIES
7.2.1.1 Using best available projections, calculate utility electrical costs over the life cycle of an installed wind energy system.	a. Plot out data for presentation to class.

NOTES:

MAJOR CONCEPT 7.0 RELATED FACTORS **TIME** 20 mins.

7.2 Cost-Benefit Analysis

7.2.2 Machine Amortizations

OBJECTIVES	STRATEGIES
7.2.2.1 Calculate the amortization of a wind electric system based on machine life cycle output.	a. Illustrated lecture showing mathematical calculations necessary to determine paybacks.
7.2.2.2 Compare utility supplied power to wind machine supplied power and determine overall cost effectiveness.	

NOTES:

MAJOR CONCEPT 7.0 RELATED FACTORS **TIME** 20 mins.

7.2 Cost-Benefit Analysis

7.2.3 Maintenance Costs

OBJECTIVES	STRATEGIES
7.2.3.1 List several periodic maintenance procedures for wind systems. 7.2.3.2 Produce an annual maintenance schedule with projected costs for a small residential wind energy system.	a. Compile and discuss with class, maintenance procedures for a variety of commercially-produced systems.

NOTES:

MAJOR CONCEPT 7.0 RELATED FACTORS **TIME** 15 mins.

7.2 Cost-Benefit Analysis

7.2.4 Tax Incentive

OBJECTIVES	STRATEGIES
7.2.4.1 Specify current applicable tax incentives related to the installation of residential wind energy system.	a. Discuss and analyze updated tax incentive material applicable to wind energy installations.

NOTES:

MAJOR CONCEPT 7.0 RELATED FACTORS **TIME** 30 mins.

7.3 National, Political & Legal

7.3.1 Topical-Current

OBJECTIVES	STRATEGIES
7.3.1.1 Identify and discuss topics of current concern on either a local or national level.	a. Discuss with class the realities of wind-powered electrical generation on both a small and large scale basis. Consider also the use of wind energy for other tasks in addition to electrical generation. b. Make bulletin board display with current articles from newspapers and magazines concerning wind energy.

NOTES:

EVALUATION OF COMPETENCIES

Time did not permit the development of an extensive evaluation plan for this instructional package. However, a chart for evaluating the very basic competencies that a student should acquire through instruction, has been developed. The chart is in the form of a profile which can be used as a checklist to show the performance level of a student, relative to several basic competencies. The chart which appears on the next page, lists the basic competencies in the left hand column. The columns on the right relate to the performance level obtained by the student for each competency. The teacher and/or the student can select the performance level for each competency using one of the following keys:

If the competency is a manipulative skill, one of the following numbered columns is checked:

0 = Unacceptable
1 = Introduced
2 = Requires Supervision
3 = Works Independently

If the competency is a cognitive skill (e.g. understanding information) one of the following numbered columns is checked:

0 = Unacceptable
1 = Average
2 = Above Average
3 = Superior

A variety of evaluation devices will need to be developed by the teacher to provide the information necessary for accurately completing the profile chart. These devices will vary with individual teachers, but will probably include written tests, manipulative performance tests, teacher observations and student self-evaluations to name a few.

Although the task of constructing these devices has been left up to the individual teacher, project staff felt that this task will be facilitated by referring to the educational objectives listed for each third level concept. The objectives have been written in behavioral terms and provide a definitive statement regarding what the student should know or be able to do. Written in this fashion, the objectives should provide the teacher with the primary information needed for the development of various evaluation instruments.

BASIC COMPETENCY PROFILE CHART

Wind Energy

Competencies	Performance Level				
	*	0	1	2	3
1. Understanding historical development of wind energy.					
2. Analyzing growth, decline and rebirth of wind energy.					
3. Calculating energy and power requirements.					
4. Describing basic methods of mechanical power transmission and control.					
5. Analyzing various factors in wind generator site selection.					
6. Using wind instruments to collect data.					
7. Processing wind data for site selection.					
8. Describing various wind machine configurations and their advantages and disadvantages.					
9. Describing major mechanical components of wind systems.					
10. Identifying major types of windmill support structures.					
11. Correlating blade design, rotor configuration and rpm to wind machine end use.					
12. Diagramming various wind energy storage systems.					
13. Differentiating among various inversion systems.					
14. Identifying various legal aspects involved in various wind energy systems.					
15. Designing a small scale electrical or mechanical wind system.					
16. Identifying safety procedures involved in the installation, operation, and maintenance of wind energy systems.					
17. Calculating cost benefit analysis of wind energy systems.					
18. Identifying environmental concerns of wind systems.					

*KEY	If a Manipulative Skill, Check	If Information, Check
	0 = Unacceptable	0 = Unacceptable
	1 = Introduced	1 = Average
	2 = Requires Supervision	2 = Above Average
	3 = Works Independently	3 = Superior

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Noyes Data Corporation. Wind Power. Mill Road at Grand Ave., Park Ridge, N.J.: Noyes Corp., 07656, 1979.

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Prenis, John ed. *Energy Book #1 Natural Sources and Backyard Applications.* Philadelphia, Pa.: The Running Press, 38 South 13th St., 1976.

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Revised Supplement to Jacobs Instruction Manual. Available from North Wind Power Co., Box 315, Warren, Vt. 05674.

Torrey, Volta. *Wind-Catchers*. Brattleboro, Vt., 1976.

Wind Bibliography. Available from National Center for Appropriate Technology, P.O. Box 3838, Butte, Mont. 59701.

Wind Energy Bibliography. Available from Windworks, Box 329, Route 3, Mukwonago, Wisc. 53149.

Wind Power Digest. 109 E. Lexington, Elkhart, Ind. 46514.

References

Aeromotor Division-Braden Industries, P.O. Box 1364, Conway, Ariz. 72032 (Water Pumping Wind Systems).

American Wind Energy Association, 54468, CR 31, Bristol, Indiana 46507.

Dempster Industries, Inc., P.O. Box 848, Beatrice, NB 68319. (Water Pumping Wind Systems).

Dyna Technology, Inc., Ecological Science Corp., Sioux City, Iowa 51102. (Wind Systems)

Enertech Corp., P.O. Box 420, Norwich, Vt. 05055. (Wind Systems)

Heller Aller Co., Perry and Oakwood Sts., Napoleon, OH 43545. (Water Pumping Wind Systems)

New Jersey Department of Energy, 101 Commerce St., Newark, N.J. 07102. Hot Line #800-492-4242 (Information on WECS installation).

Northwind Power Company, Inc., P.O. Box 315, Warren, Vt. 05674 (Wind Systems)

Unarco-Rohn, Division of Unarco Industries, Inc., 6718 West Plank Rd., P.O. Box 2000, Peoria, Il. 61656 (Towers)

Windworks, Box 329, Route 3, Mukwonago, Wi. 53149. (Inverters and Wind Systems).

Field Trips-WECS

The following sites appear to be suitable for field trips. It is strongly recommended that arrangements be made in writing prior to the actual field trip.

Maglio Construction Company, Curridan Ave., Clarksboro, N.J. Contact: Mr. Vito Maglio. (40 KW Merkam wind-powered turbine.)

Mainland Regional High School, Linwood, N.J. 08221. Contact: Mr. Douglas String, Industrial Arts Dept. (Experimental wind-powered electric generator to be constructed in 1980-81.)

Mohican Outdoor Resource Center, Gaisler Rd., Blairstown, N.J. Contact: Dr. Robert D. Weber, Trenton State College, Trenton, N.J. 08625. (3 KW Jacobs wind-powered electric generator with Gemini Synchronous Inverter.)

Monmouth Museum, Lincroft, N.J., 07738. Contact: Dorothy Morehouse, Director (40 KW Merkam wind-powered turbine will be used for electrical resistance heating.)

Montclair State College, Department of Industrial Education and Technology, Upper Montclair, N.J. 07043. Contact: Dr. Martin Greenwald. (2 KW Jacobs wind-powered electric generator.)

Neptune Junior High School, 2300 Heck Ave., Neptune, N.J. 07753. Contact: Mr. Ron Gorsky, Industrial Arts Department. (Experimental wind-powered electric generator constructed by junior high school students.)

Princeton Education Center, Blairstown, N.J. 07825. (Sail-wing wind-powered generator.)

Ramapo Community College, Ramapo Valley Road, Mahwah, N.J. 07430. Contact: Professor William Makofski. (Jacobs 2 KW wind turbine with battery storage system, also, Baker wind-powered water pumping machine used for irrigation.

Somerset County Park Commission, Environmental Education Center, Lord Sterling Road, Basking Ridge, N.J. 07920. Contact: Joanne Hitt. (Winco Wind Turbine--generates electrical power for operating water pump motor. (Battery storage) Also, experimental wind turbine--a project of Rutgers University Graduate Department of Mechanical Engineering.

Trenton State College, Division of Industrial Education and Technology, Trenton N.J. Contact: Dr. John Hutchinson or Dr. Norman Asper. (3 KW Jacobs wind-powered electric generator with Gemini Synchronous Inverter.)

Volendam Windmill Museum, Inc., Adamic Hill Road, R.D. 1, Box 242, Milford, N.J. 08848. Mr. Paul Jorgenson, Curator. (Restored 60' high windmill used for grinding grain into flour.)

West Milford High School, Industrial Arts Department, West Milford, N.J. (Jacobs 2 KW wind turbine with synchronous inverter.)

Films, Slides and Filmstrips

Dawn of the Solar Age: Wind and Water Energy (video cassette, 25 mins.), available from Time/Life Video, Time/Life Building, New York, N.Y.

Fitterling, John A., Basic Electrical Concepts. St. Louis, Mo.: Milliken Publ Co., 1976. 16 Transparencies, 12 duplicating pages and teacher's guide.

Magnetism and Electricity for Grades 5 to 9. St. Louis, Mo.: Milliken Pub. Co., 1966. (20 transparencies, 20 duplicating pages.)

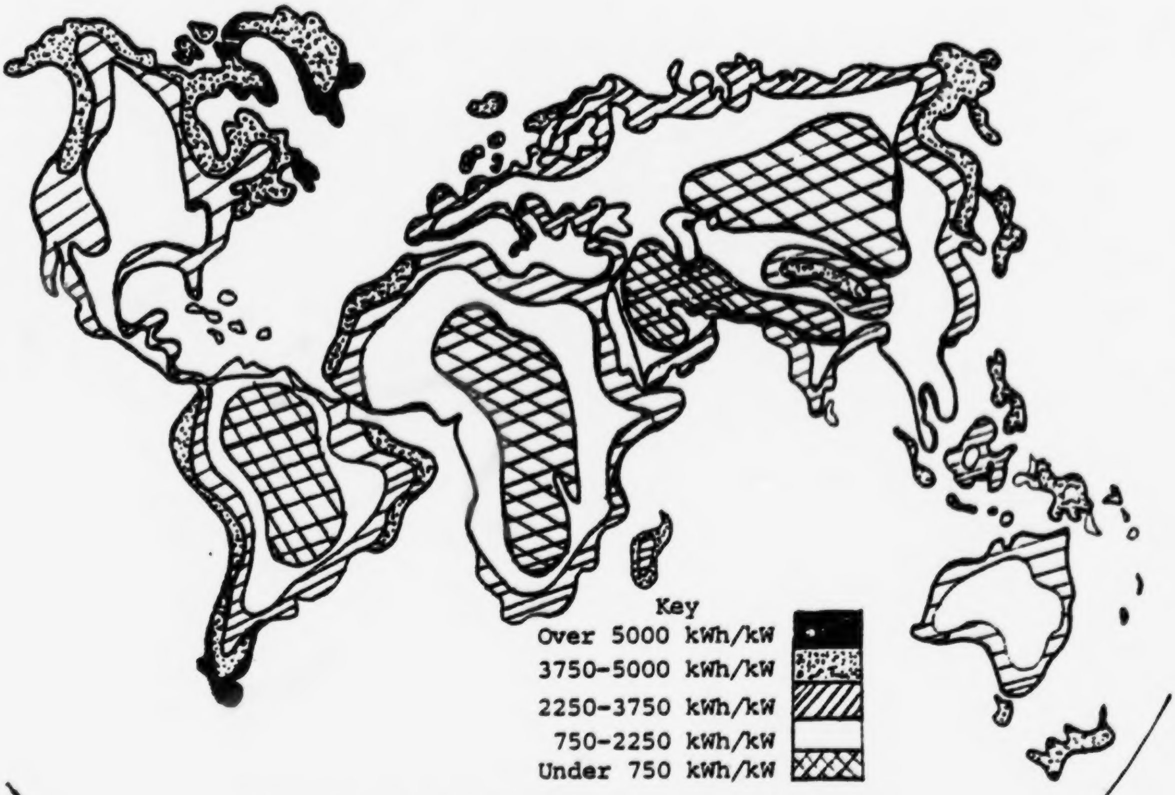
Gusts of Power (16 mm film), available from D.O.E. Film Library, Technical Information Center, P.O. Box 62, Oakridge, Tenn. 37830.

The Winds of Change (16 mm film, 5½ mins), available from McDonnell Douglas Corp., St. Louis Library, Dept. 091, Bldg. 034, P.O. Box 516, St. Louis, Mo. 63166.

Wind Power-The Great Revival (16 mm film, 29 mins.), available from University of Colorado, Educational Media Center, Boulder, Co. 80309

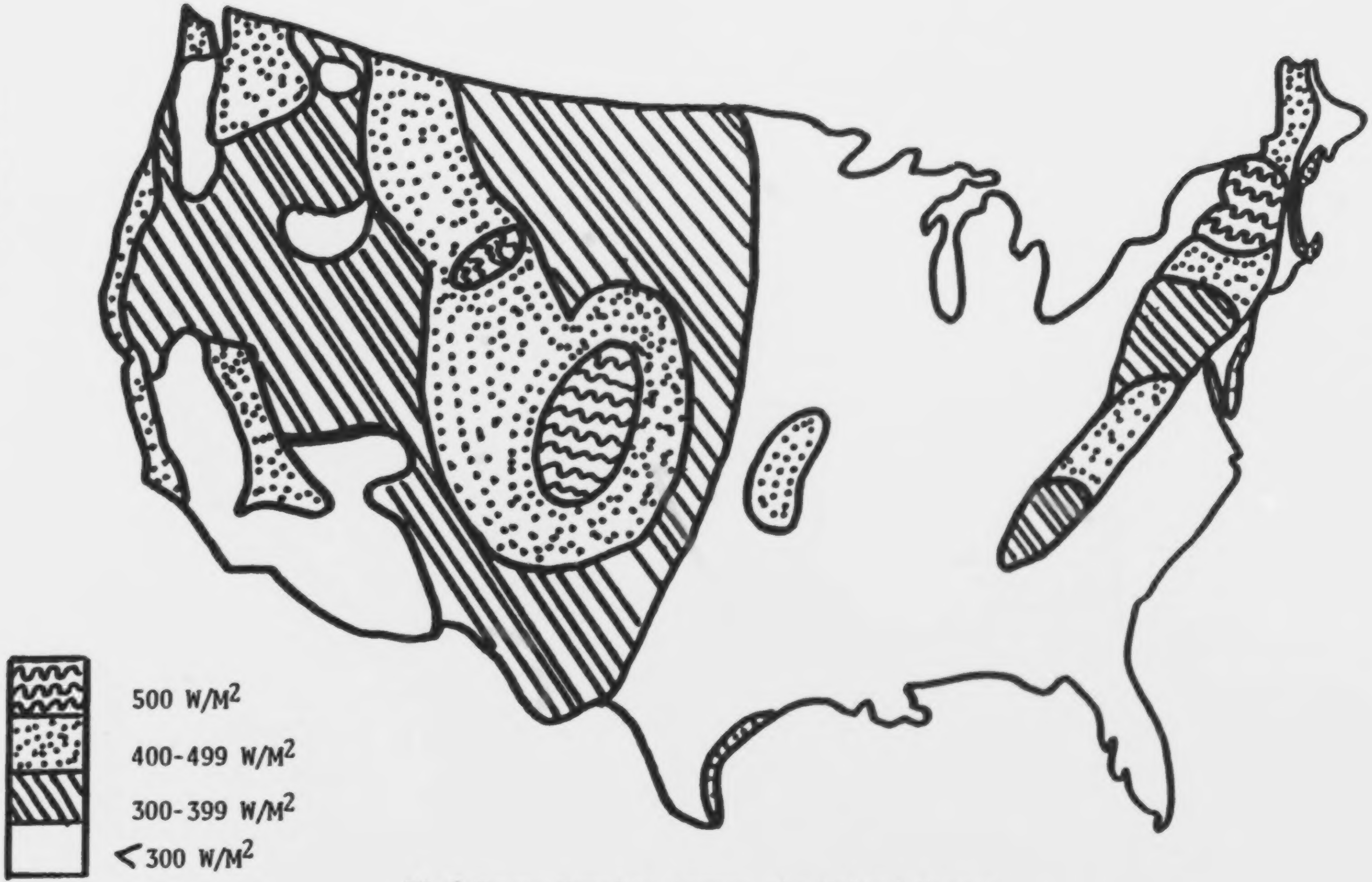
TRANSPARENCY #1

ANNUAL AVAILABILITY OF WIND ENERGY IN DIFFERENT PARTS OF THE WORLD


Key
Over 5000 kWh/kW ■
3750-5000 kWh/kW ▒
2250-3750 kWh/kW ▨
750-2250 kWh/kW □
Under 750 kWh/kW ▩

In Terms of Estimated Number of kWh/Year per Rated Kilowatt Output for Wind Machines Designed for Rated Wind Speeds of 25 Miles per Hour

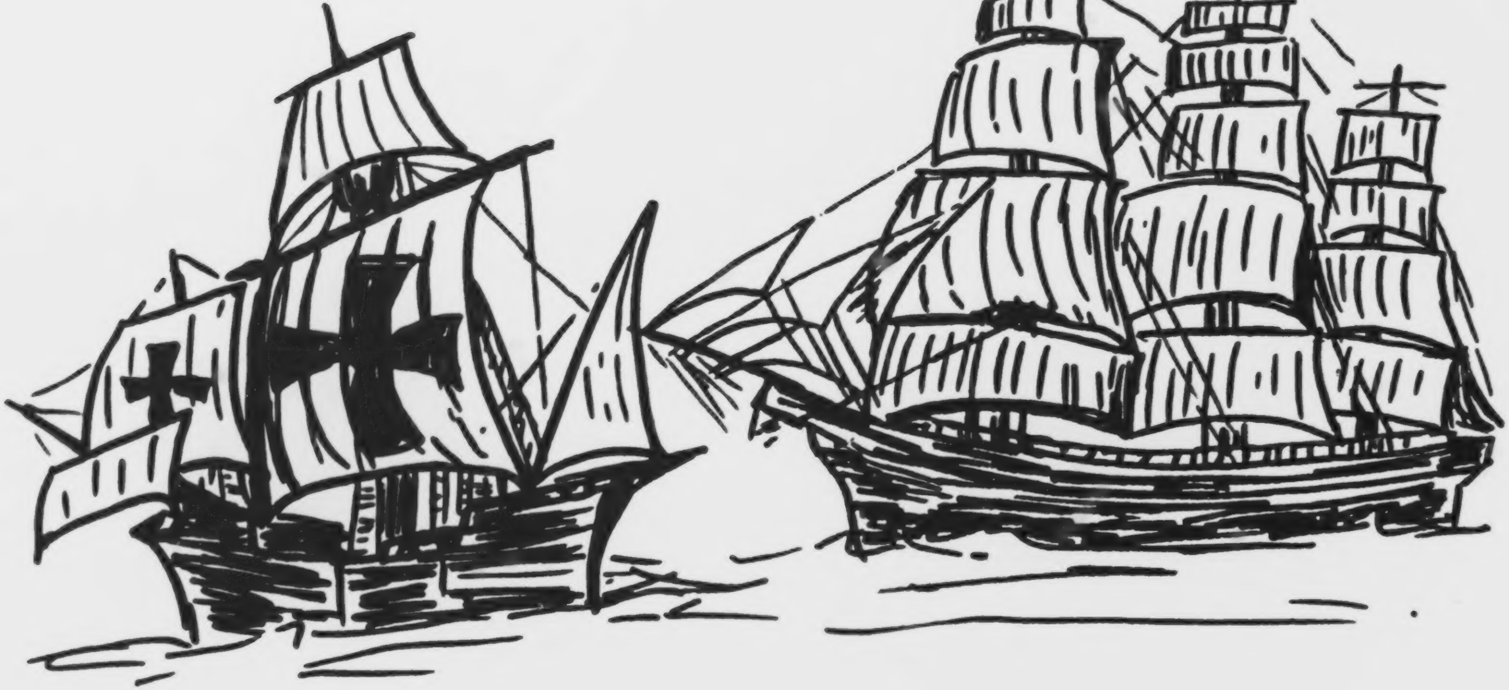
TRANSPARENCY #2


▨ 500 W/M²
▨ 400-499 W/M²
▨ 300-399 W/M²
☐ < 300 W/M²

Wind Power Density Across the United States

Adapted from Electric Power Research Institute Journal, March 1980.

TRANSPARENCY #3

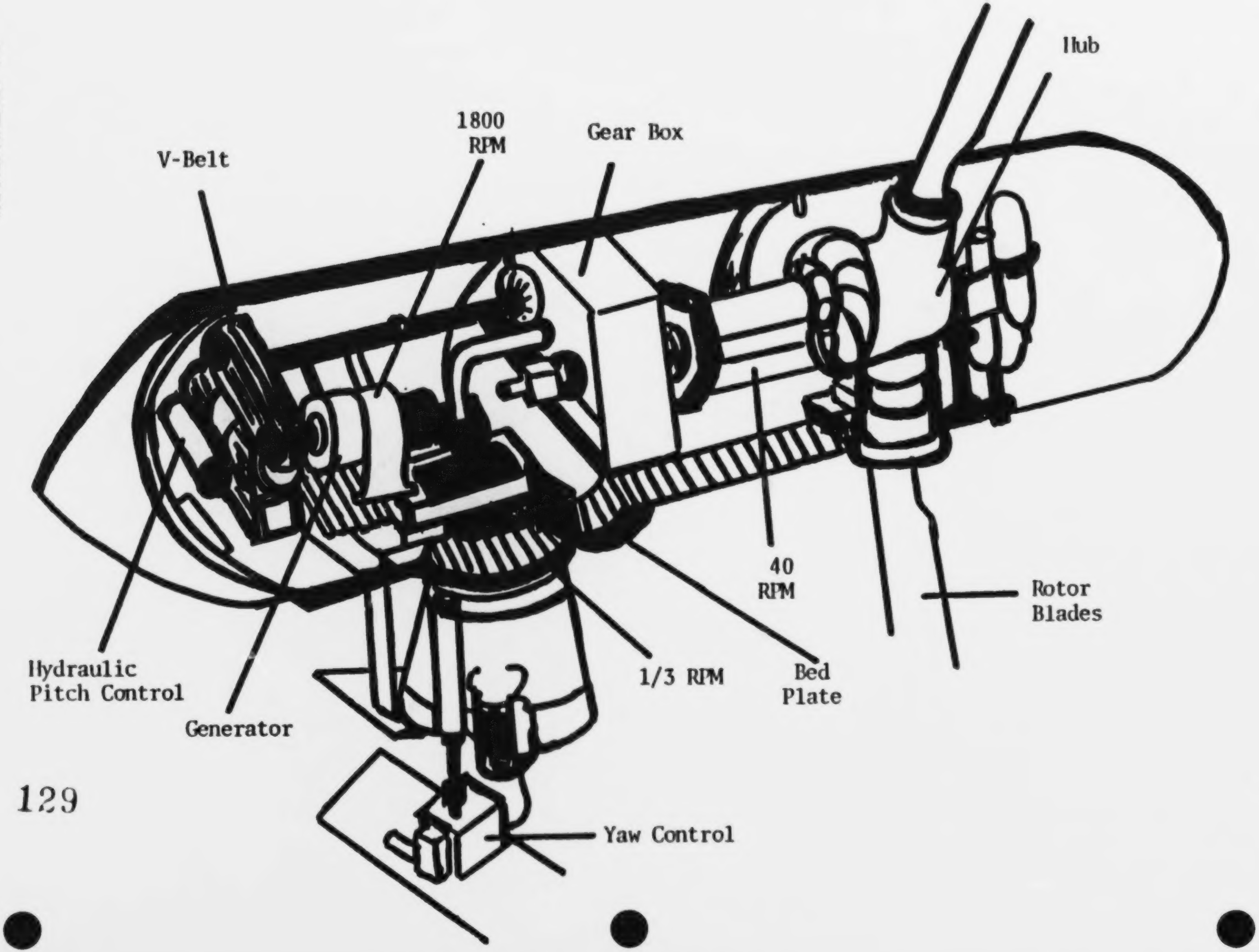


TRANSPARENCY #1

	MOD-0	MOD-0A	MOD-1	MOD-2
Tower height	100 ft.	100 ft.	135 ft.	200 ft.
Rotor blade span	125 ft.	125 ft.	200 ft.	300 ft.
Rated power output for rated wind speed	100kW	200kW	2.0MW	2.5MW
Expected energy output per year	700MWh	820MWh	3.7GWh	9.3GWh
Cut-in/Cut-out speed	10/35mph	10/35mph	11/35mph	9/35mph
Weight/kW	800lb/kW	450lb/kW	328lb/kW	240lb/kW
Location (first rotation)	Sandusky, Ohio (1975)	Block Island, Rhode Island (1979)	Boone, N.C. (1979)	Goldendale, Washington (1980)
Prime Contractor	NASA	Westinghouse Electric Corp.	General Electric Corp.	Boeing Engineering Construction

Adapted from Electric Power Research Institute Journal, March 1980.

TRANSPARENCY #5


Hub
1800 RPM
Gear Box
V-Belt
40 RPM
Rotor Blades
Hydraulic Pitch Control
Generator
1/3 RPM
Bed Plate
Yaw Control

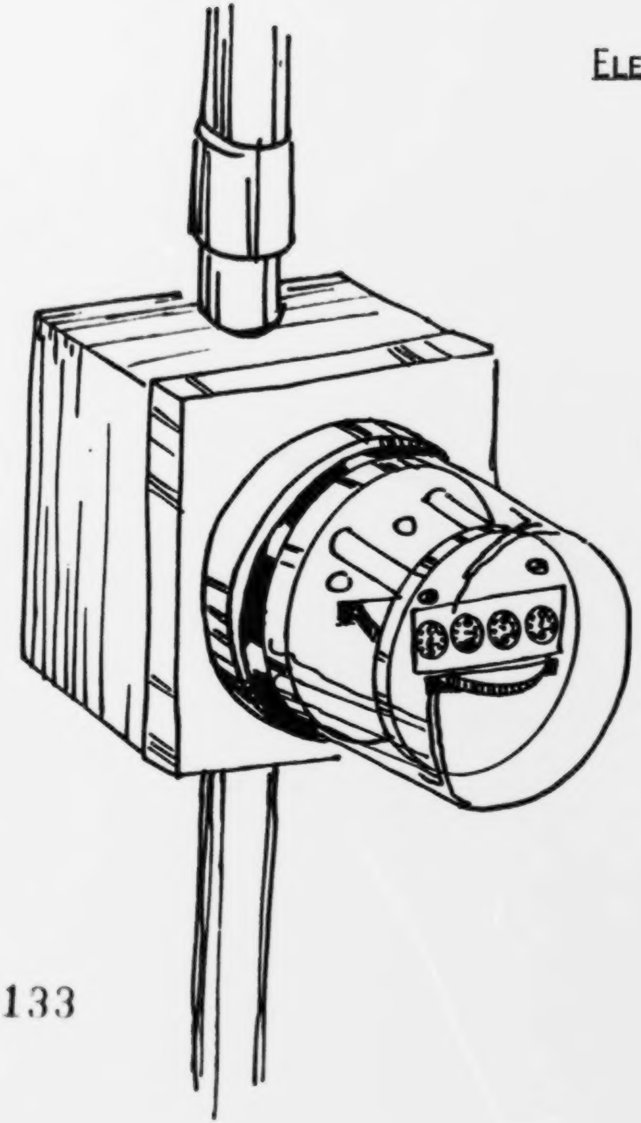
TRANSPARENCY #6

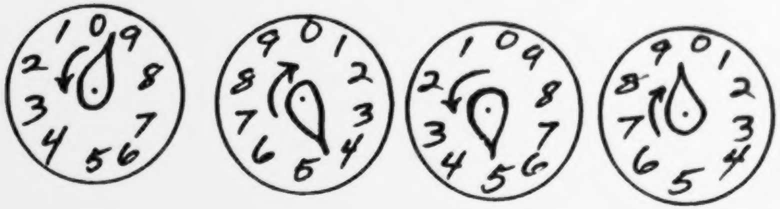
ENERGY : POWER TO DO WORK

POWER : ENERGY OVER UNIT TIME

TRANSPARENCY #7

ELECTRIC METER

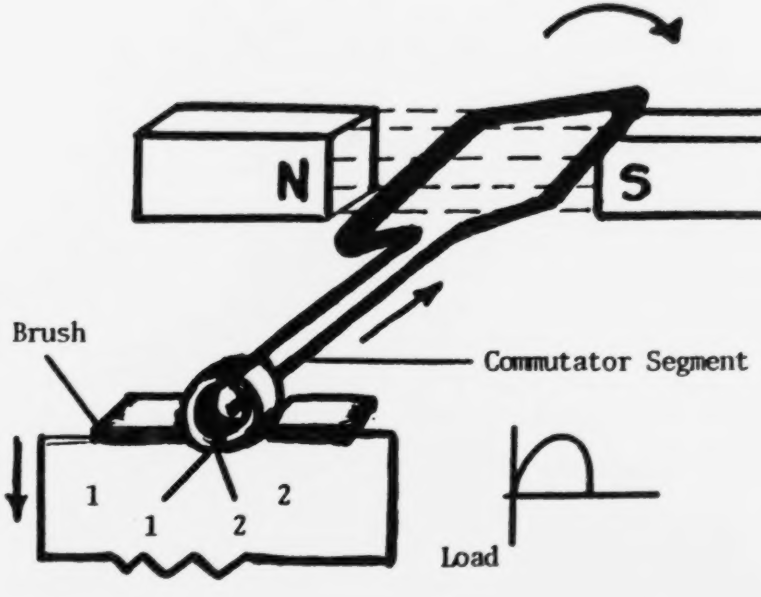



1 0 9 2 8 3 7 4 5 6
9 0 1 8 2 7 3 6 5 4
1 0 9 2 8 3 7 4 5 6
9 0 1 8 2 7 3 6 5 4

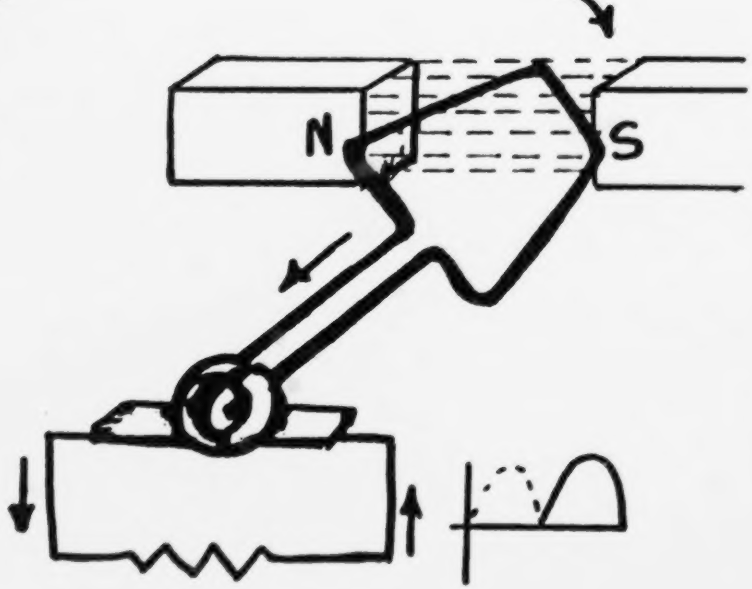
READING = 9,449 KHW

TRANSPARENCY #8

BASIC OPERATION OF A DIRECT CURRENT GENERATOR


N
S
Brush
Commutator Segment
1
1
2
2
Load

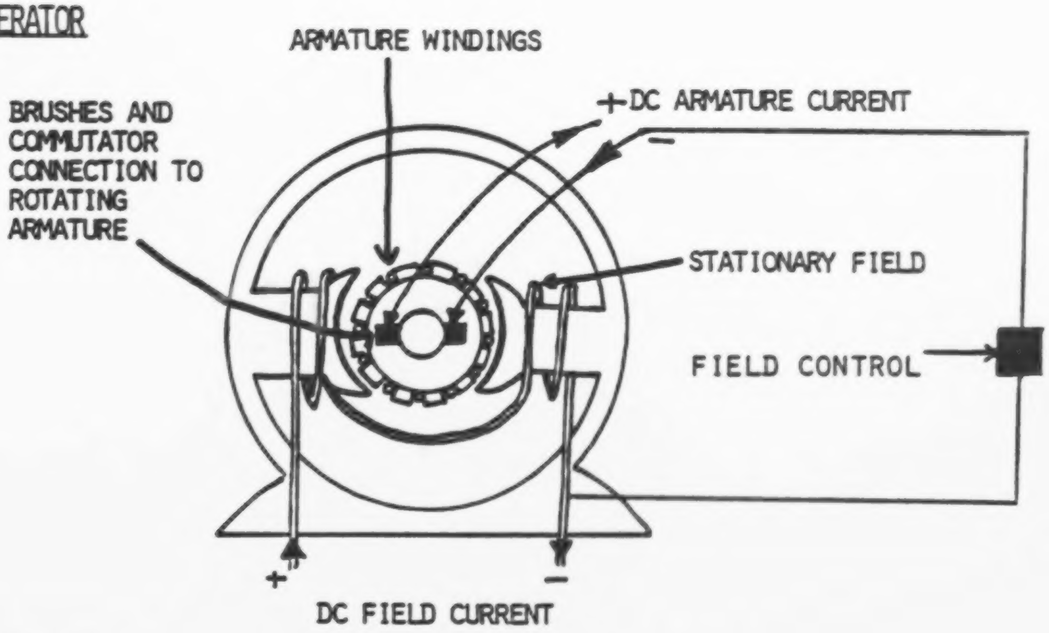
A



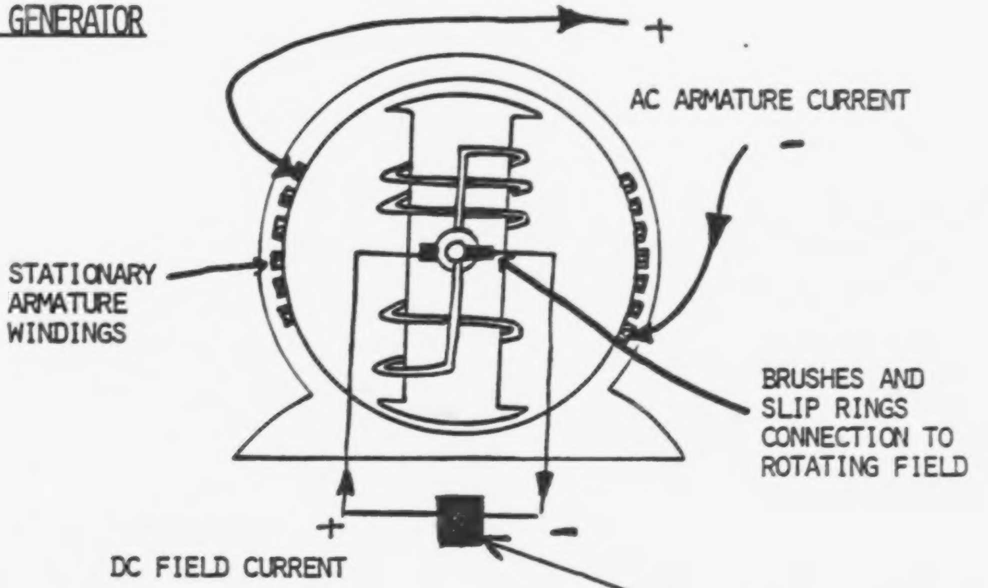
Adapted from Understanding Electricity and Electronics, Burban, Peter, and Schmitt, Marshan, 1975.

DC GENERATOR
VS
AC GENERATOR

DC GENERATOR

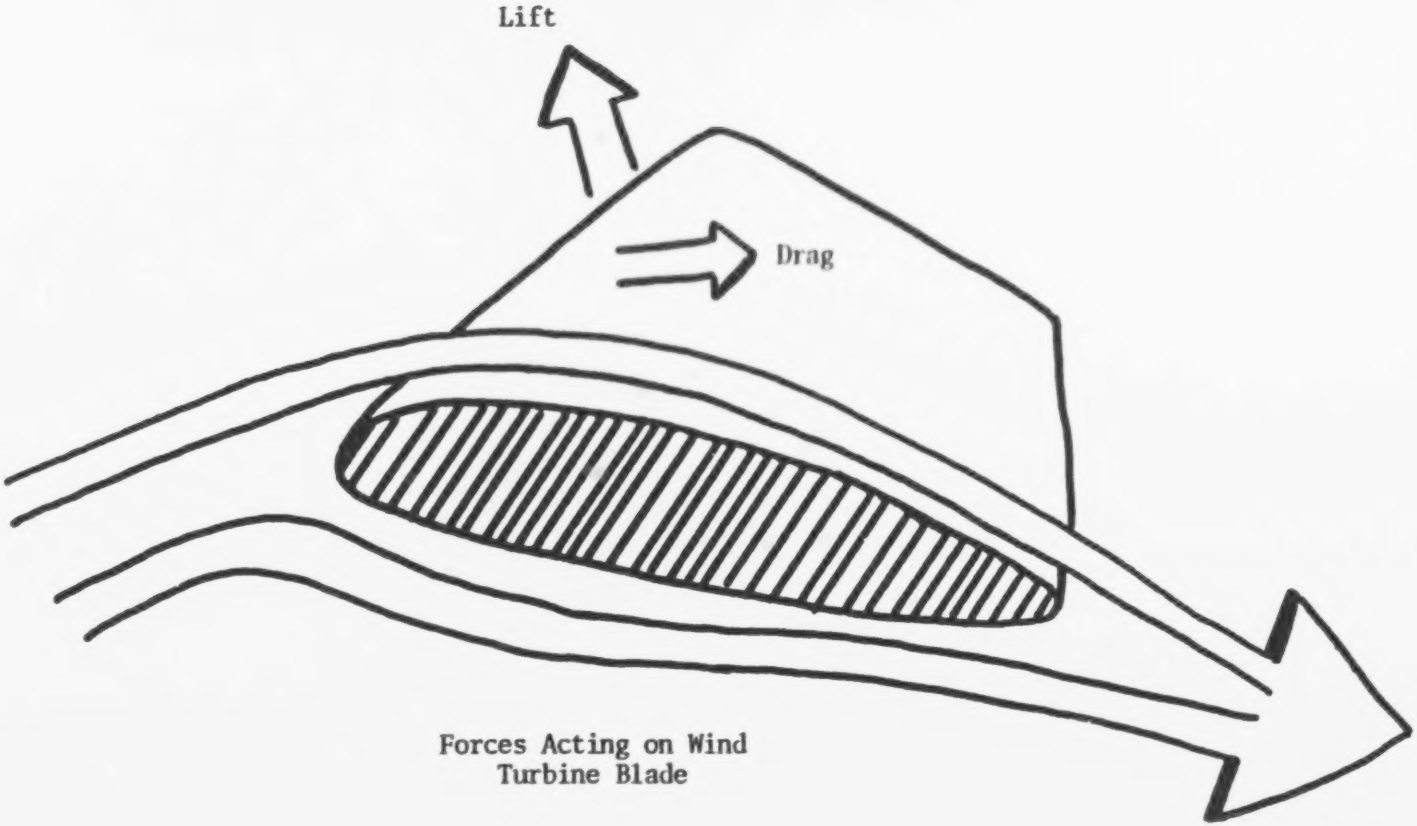

ARMATURE WINDINGS
+DC ARMATURE CURRENT
−
BRUSHES AND COMMUTATOR CONNECTION TO ROTATING ARMATURE
STATIONARY FIELD
FIELD CONTROL
+
−
DC FIELD CURRENT

AC GENERATOR


+
AC ARMATURE CURRENT
−
STATIONARY ARMATURE WINDINGS
BRUSHES AND SLIP RINGS CONNECTION TO ROTATING FIELD
+
−
DC FIELD CURRENT
FIELD CONTROL

Adapted from Other Homes and Garbage
Leckie, Masters, Whitehouse and Young, 1975.

TRANSPARENCY #10



Forces Acting on Wind
Turbine Blade

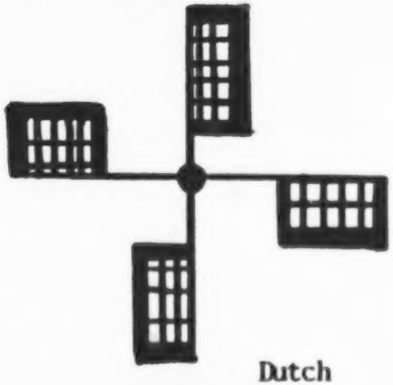
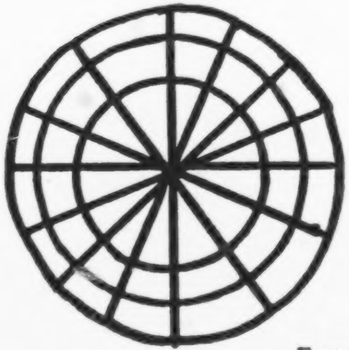
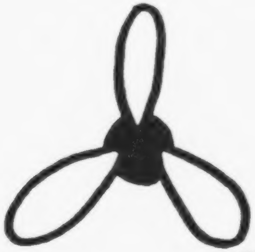
TRANSPARENCY #11

Propeller Diameter in feet	Wind Velocity in mph					
	5	10	15	20	25	30
2	0.6	5	16	38	73	130
4	2	19	64	150	300	520
6	5	42	140	340	660	1150
8	10	75	260	610	1180	2020
10	15	120	400	950	1840	3180
12	21	170	540	1360	2660	4600
14	29	230	735	1850	3620	6250
16	40	300	1040	2240	4740	8150
18	51	375	1320	3060	6000	10350
20	60	475	1600	3600	7360	12760
22	73	580	1940	4350	8900	15420
24	86	685	2300	5180	10650	18380

Windmill Power Output in Watts
assuming 70% efficiency

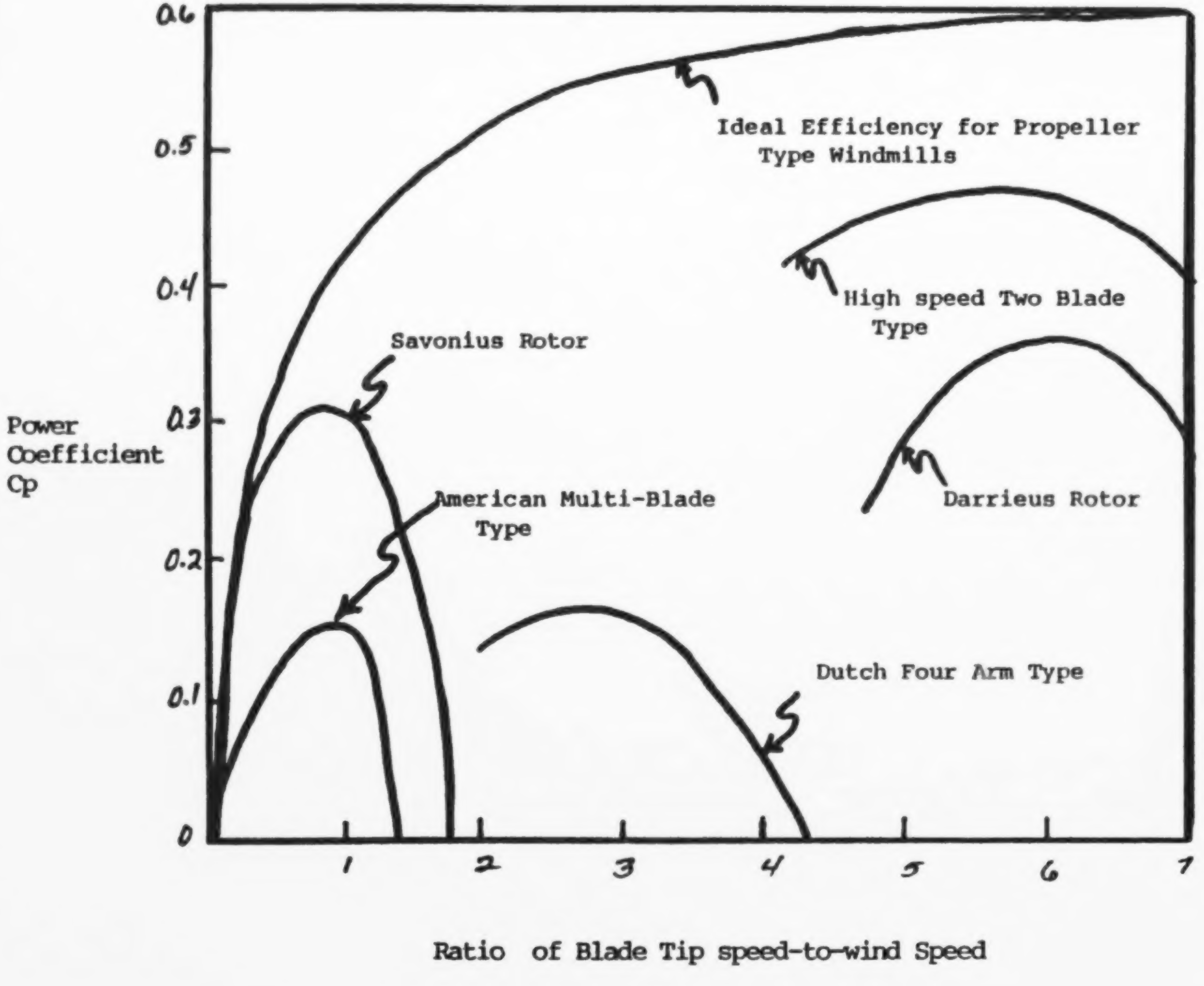
Adapted from Energy Book #1,
Prenis, 1976.

TRANSPARENCY #12

Rotor Type	Cp Max	Comments
 Dutch	0.17	High Torque, Low RPM, Inefficient Blade Design
 Farm	0.15	High Torque, Low RPM, High Losses
 Modern Propeller	0.47	Low Torque, High RPM, Efficient Blade Design

TRANSPARENCY #13

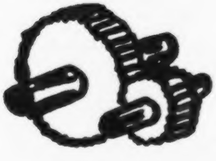
Typical Performance of Wind Machines



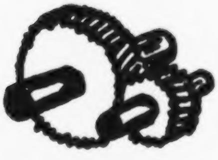
TRANSPARENCY #14

EFFICIENCY = ENERGY IN
ENERGY OUT

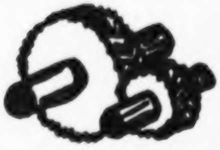
TRANSPARENCY #15



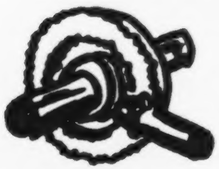
SPUR



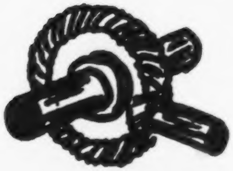
HELICAL



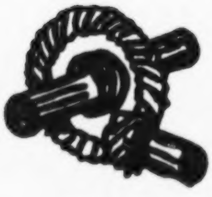
HERRINGBONE



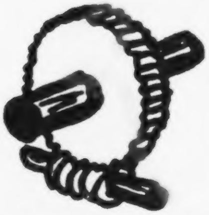
PLAIN BEVEL



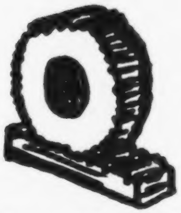
SPIRAL BEVEL



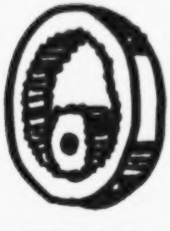
HYPOID



WORM



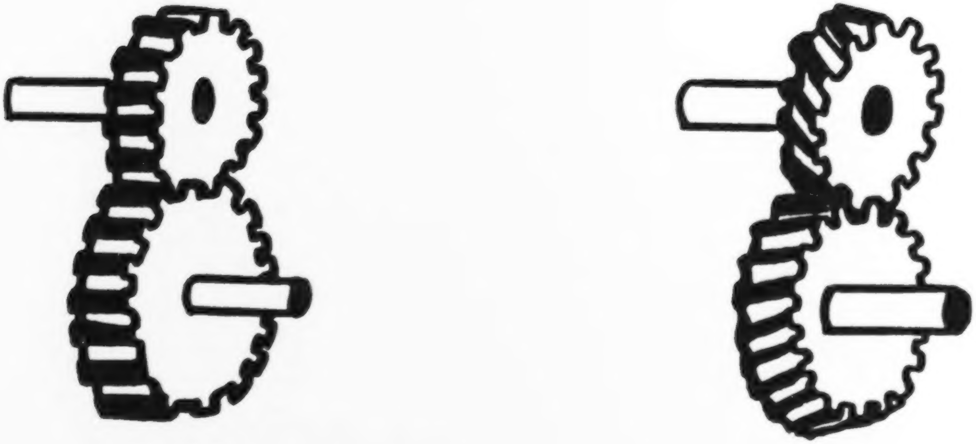
RACK AND PINION



INTERNAL

Adapted from Machine Tool Metal Working, Freirer.

TRANSPARENCY #16



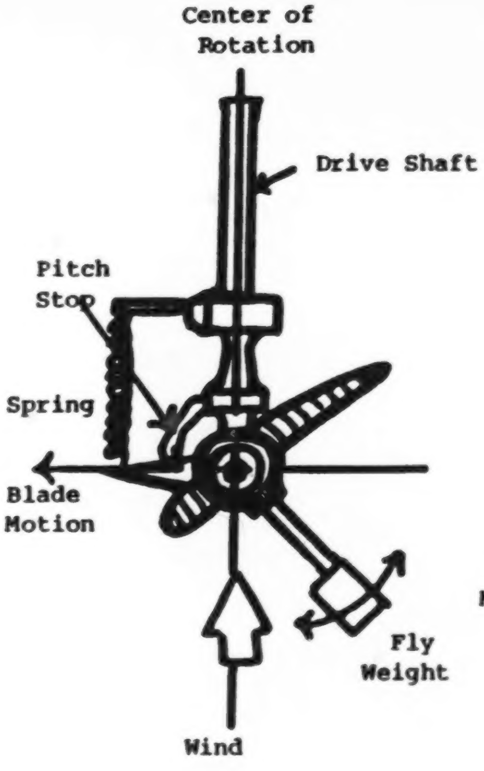
Straight Cut

Helical Cut

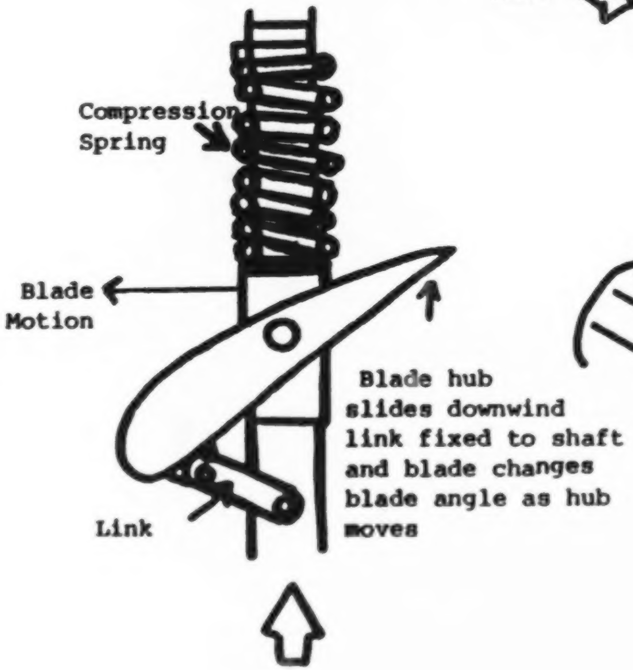
Gear Teeth Two Major Types

Adapted from Machine Tool Metal Working, Freirer.

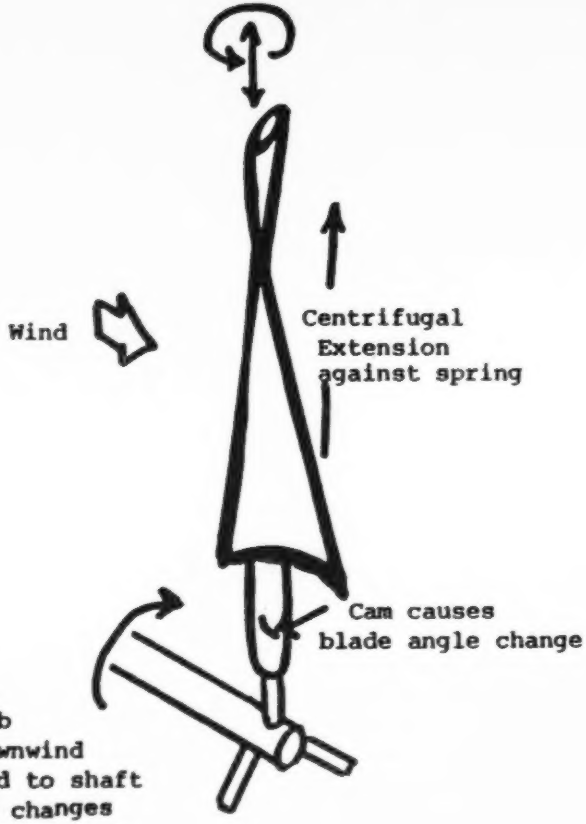
TRANSPARENCY #17


Center of Rotation
Drive Shaft
Pitch Stop
Spring
Blade Motion
Fly Weight
Wind

Fly weight Control

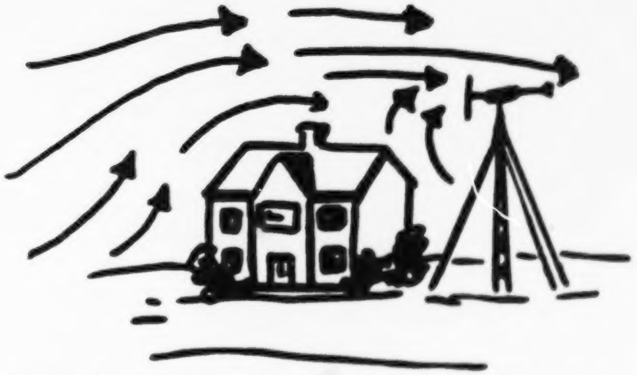

Compression Spring
Blade Motion
Blade hub slides downwind link fixed to shaft and blade changes blade angle as hub moves
Link
Wind

Sliding Hub

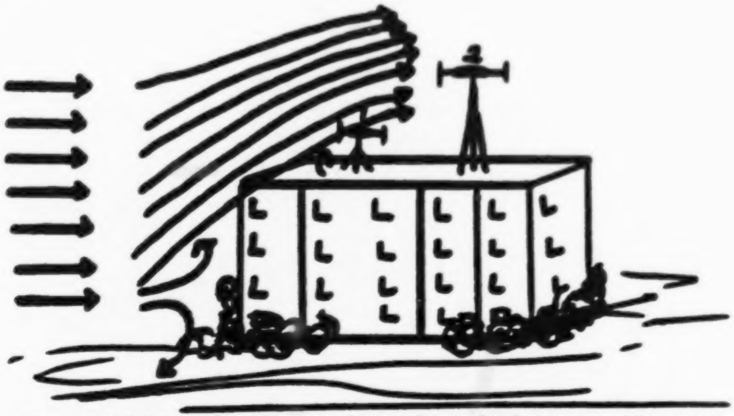

Wind
Centrifugal Extension against spring
Cam causes blade angle change

Sliding Blade Control

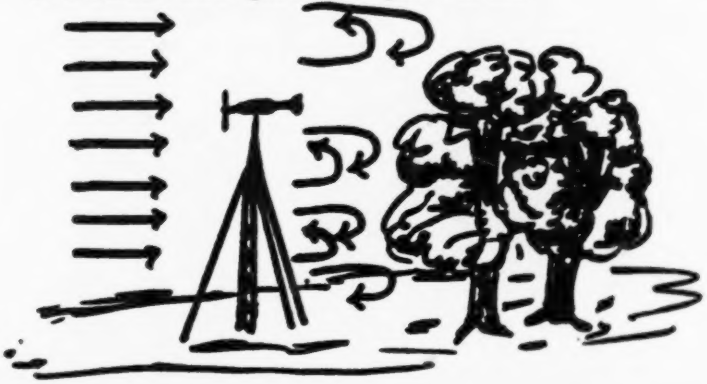
Adapted from Simplified Wind Power Systems for Experimenters, Park, 1975.



The house is diverting the windstream above the generator. The generator should be raised or moved.



The building is diverting the windstream direction, but actually increases windspeed for generator.



Obstructions cause turbulence whether they are in front of or behind the generator as here. The mast should be extended 20-30 feet above the trees, sited 300-500 feet away from them.

Adapted from Harnessing the Wind for Home Energy, McGuigan, 1978.

TRANSPARENCY #19

SUMMARY OF FEATURES OF SUITABLE SITE

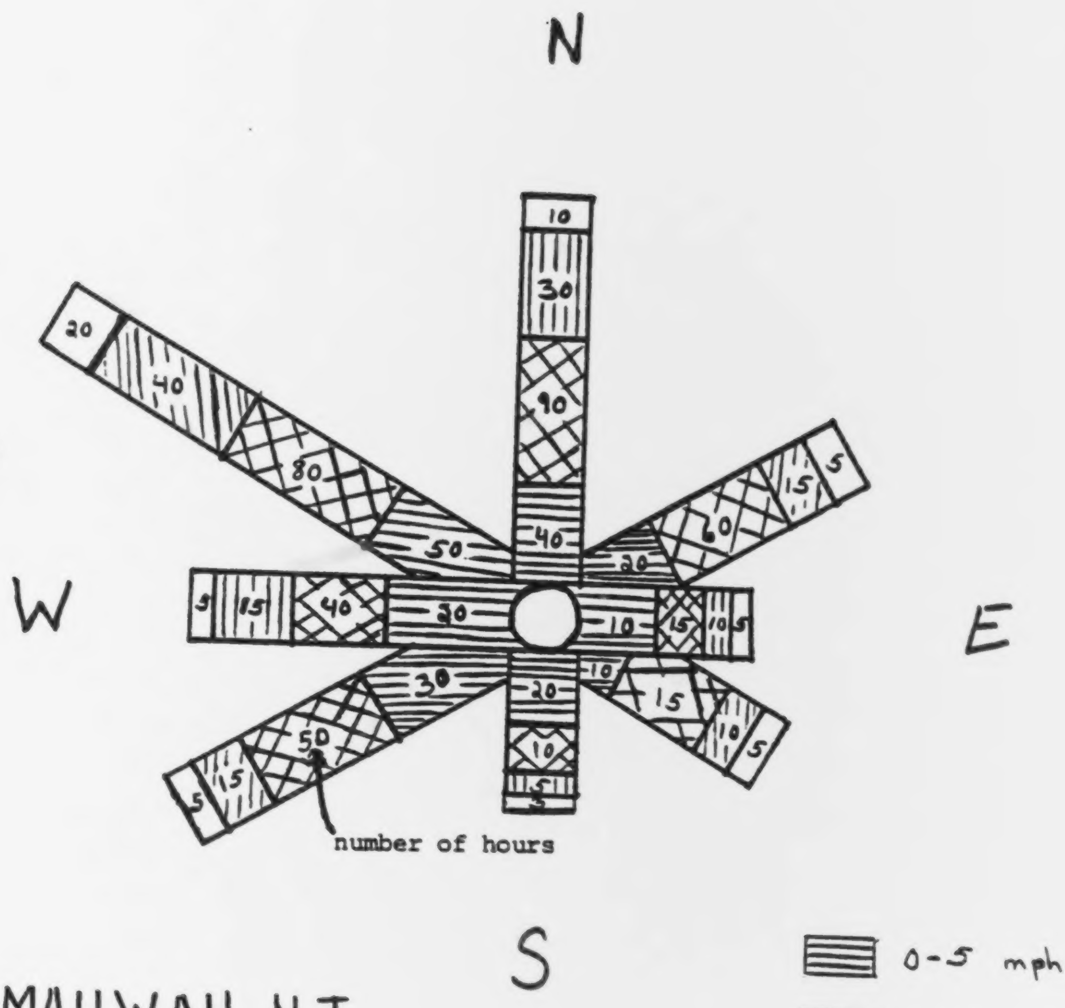
- High annual average wind speed (consult National Weather Service Station)
- No tall obstructions upwind for a distance depending on the height
- Top of smooth well-rounded hill (with gentle slopes) on flat plain or island in lake or sea
- Open plain, open shoreline
- Mountain gap that produces a funneling

TRANSPARENCY #20

BEAUFORT NUMBER	WINDSPEED M.P.H.	MEAN WIND-FORCE LB/FT^2	QUALITATIVE DESCRIPTION OF WIND
0	0-1	0	Calm. Smoke rises vertically.
1	1-3	0.01	Light air. Smoke drifts but wind vanes do not turn.
2	4-7	0.08	Light breeze. Wind vane turns. Leaves rustle.
3	8-12	0.28	Leaves and twigs in constant motion.
4	13-18	0.67	Moderate breeze. Raises dust and loose paper.
5	19-24	1.31	Small leaves begin to sway. Small crested wave force.
6	25-31	2.3	Strong breeze. Large branches move. Telephone wires whistle.
7	32-38	3.6	Moderate gale. Large trees in motion. Walking is difficult.
8	39-46	5.4	Strong gale. Extreme difficulty in walking against wind.
9	47-54	7.7	Light roofs liable to blow off houses.
10	55-63	10.5	Hurricane. Even the strongest mills liable to be damaged.

TRANSPARENCY #21

WIND ROSE

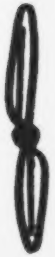


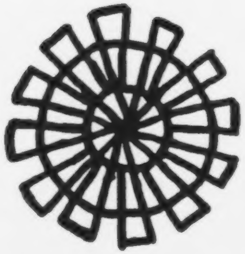
MAHWAH, N.J.
JANUARY
720 HOURS

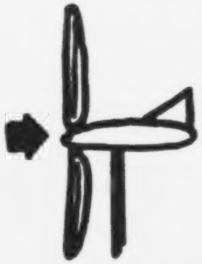
▤ 0-5 mph
▩ 5-15 mph
▥ 15-25 mph
☐ over 25 mph

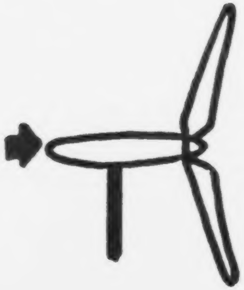
TRANSPARENCY #22

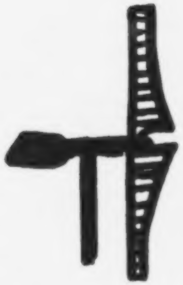
HORIZONTAL AXIS

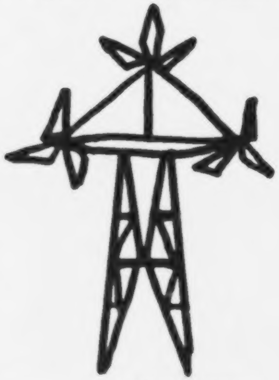

Single Blade

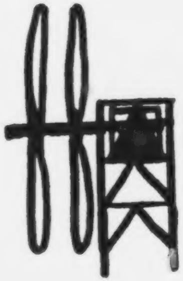

US Farm Windmill

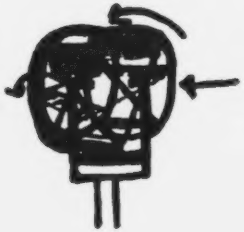

Up-wind

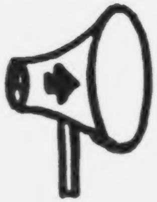

Down-wind

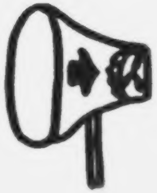

Sail wing


Multi-Rotor


Counter-Rotating
Blades

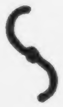

Cross-wind
Paddles


Diffuser

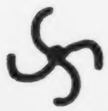

Concentrator

TRANSPARENCY #22A

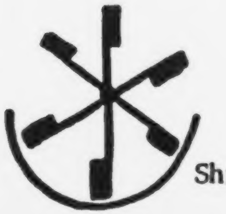
VERTICAL AXIS



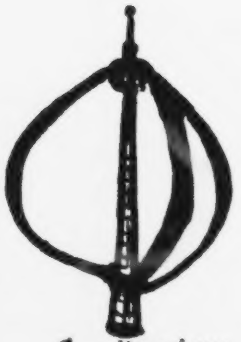
Savonius



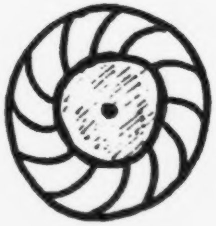
Multi-Bladed Savonius



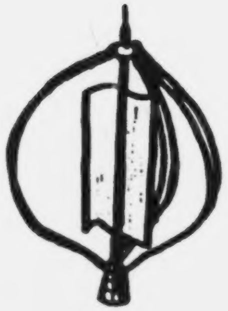
Plates



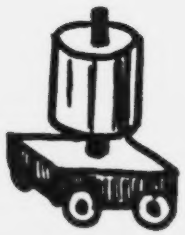
Ø - Darrieus



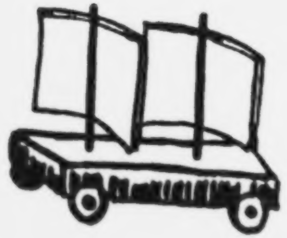
Turbine



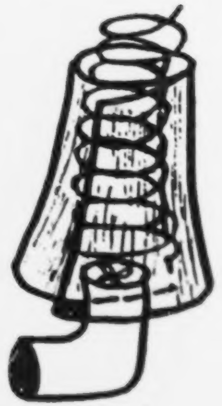
Savonius/
Ø-Darrieus



Magnus



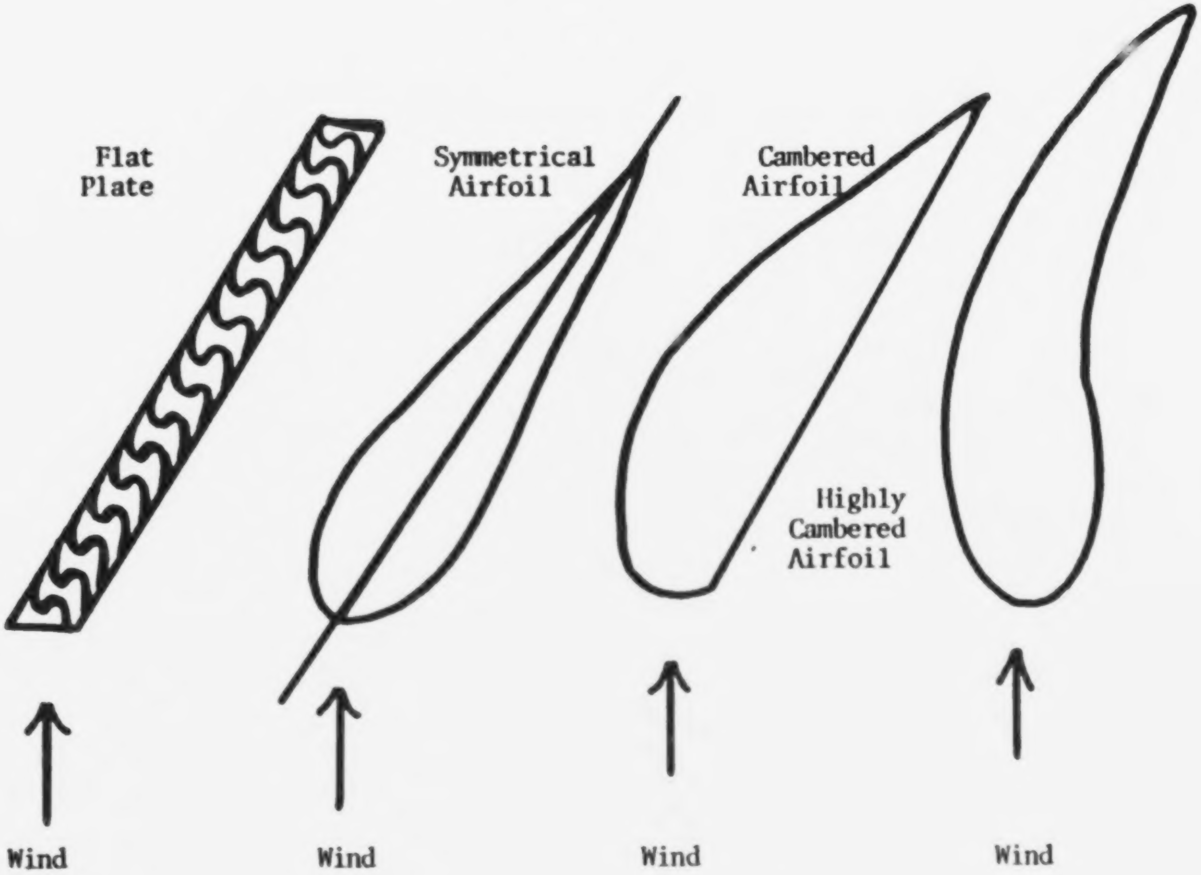
Airfoil



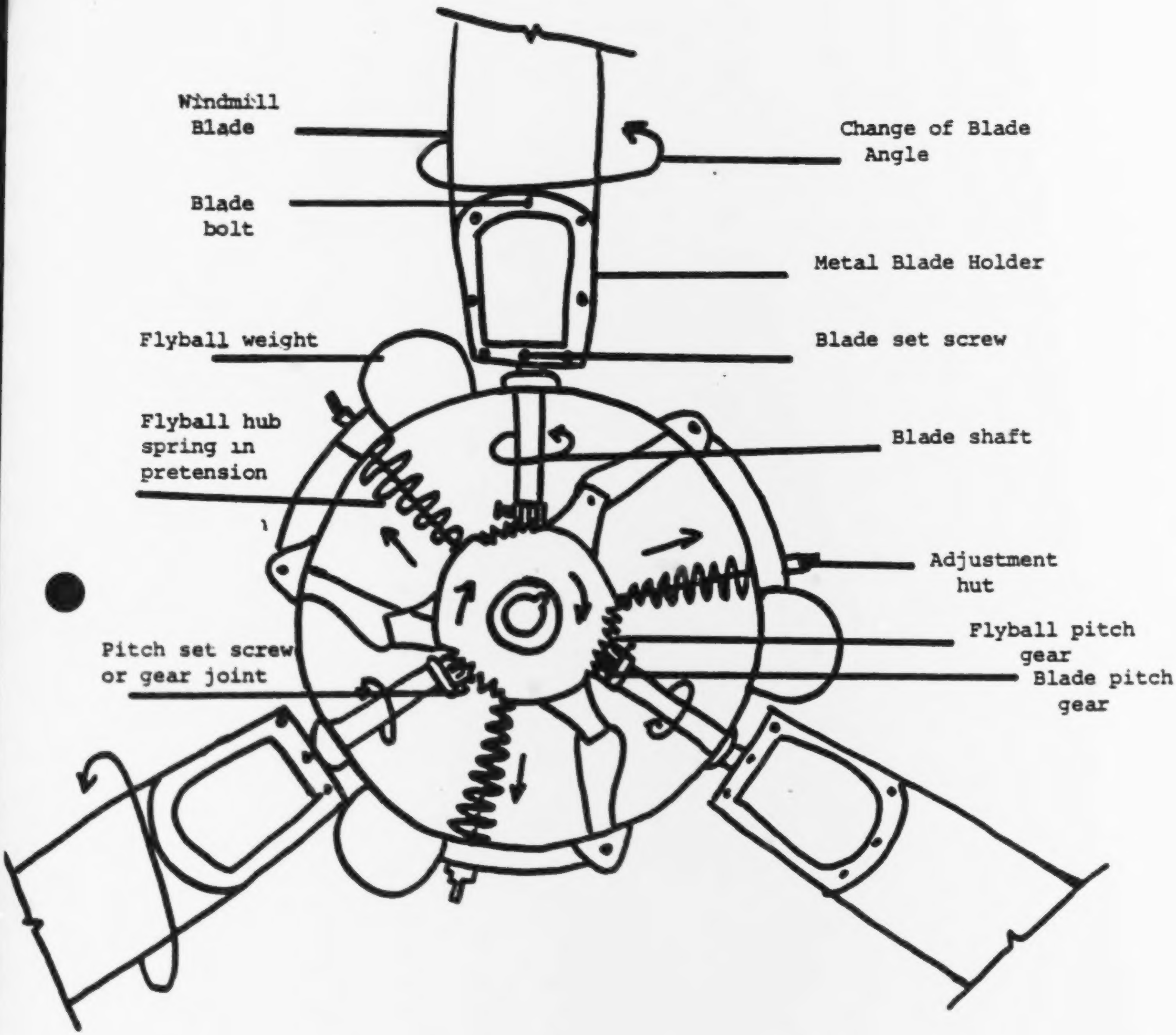
Confined
Vertex

TRANSPARENCY #23

TYPES OF AIRFOILS


Flat Plate
Symmetrical Airfoil
Cambered Airfoil
Highly Cambered Airfoil
Wind
Wind
Wind
Wind

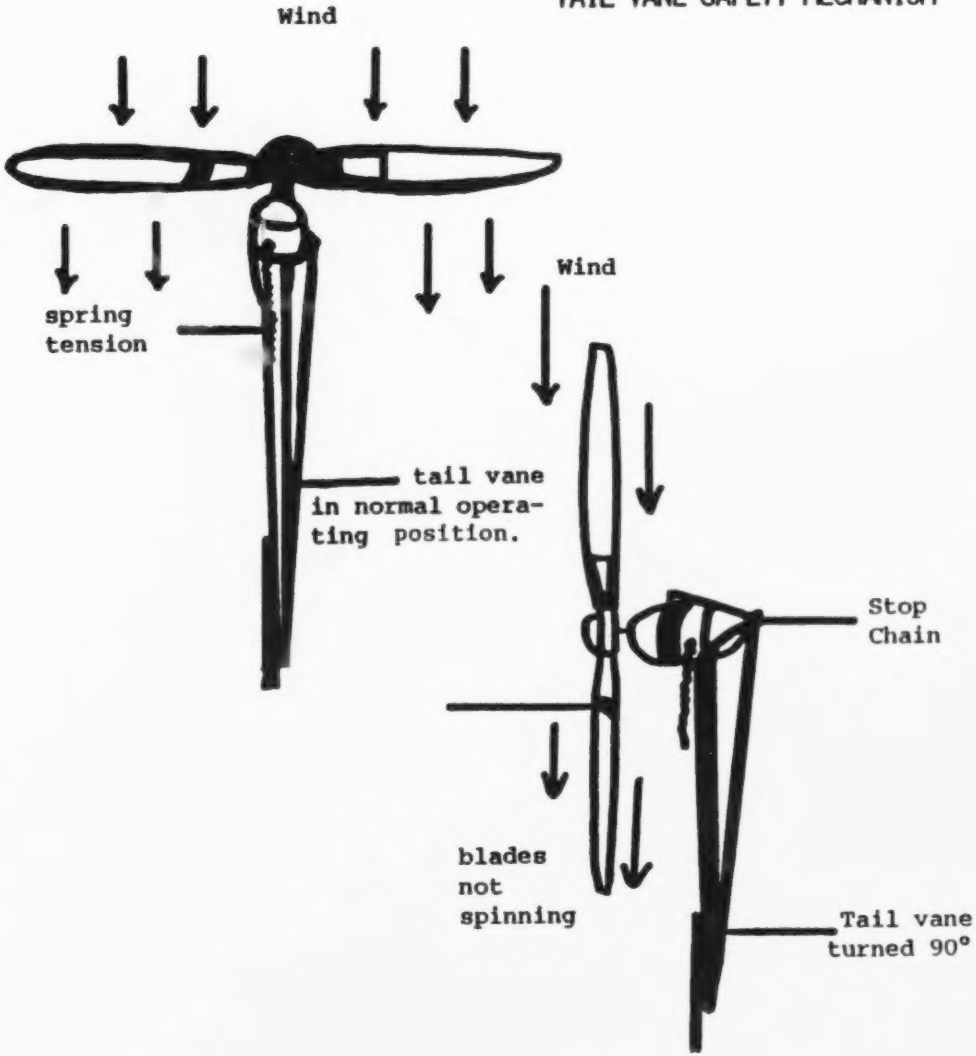
Adapted from Simplified Wind Power Systems for Experimenters, Park, 1975

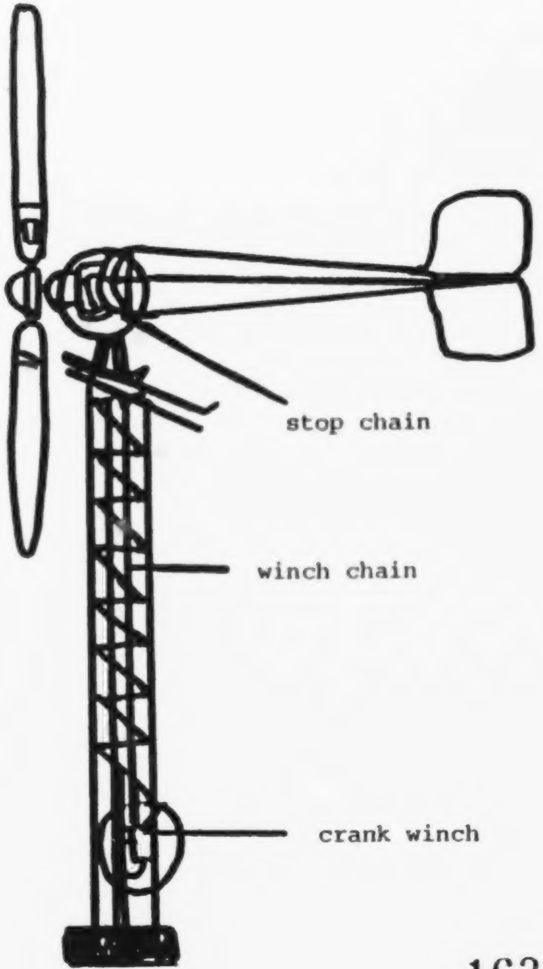

Windmill Blade
Change of Blade Angle
Blade bolt
Metal Blade Holder
Flyball weight
Blade set screw
Flyball hub spring in pretension
Blade shaft
Adjustment hut
Flyball pitch gear
Pitch set screw or gear joint
Blade pitch gear

FLYBALL OVERSPEED
SAFETY MECHANISM

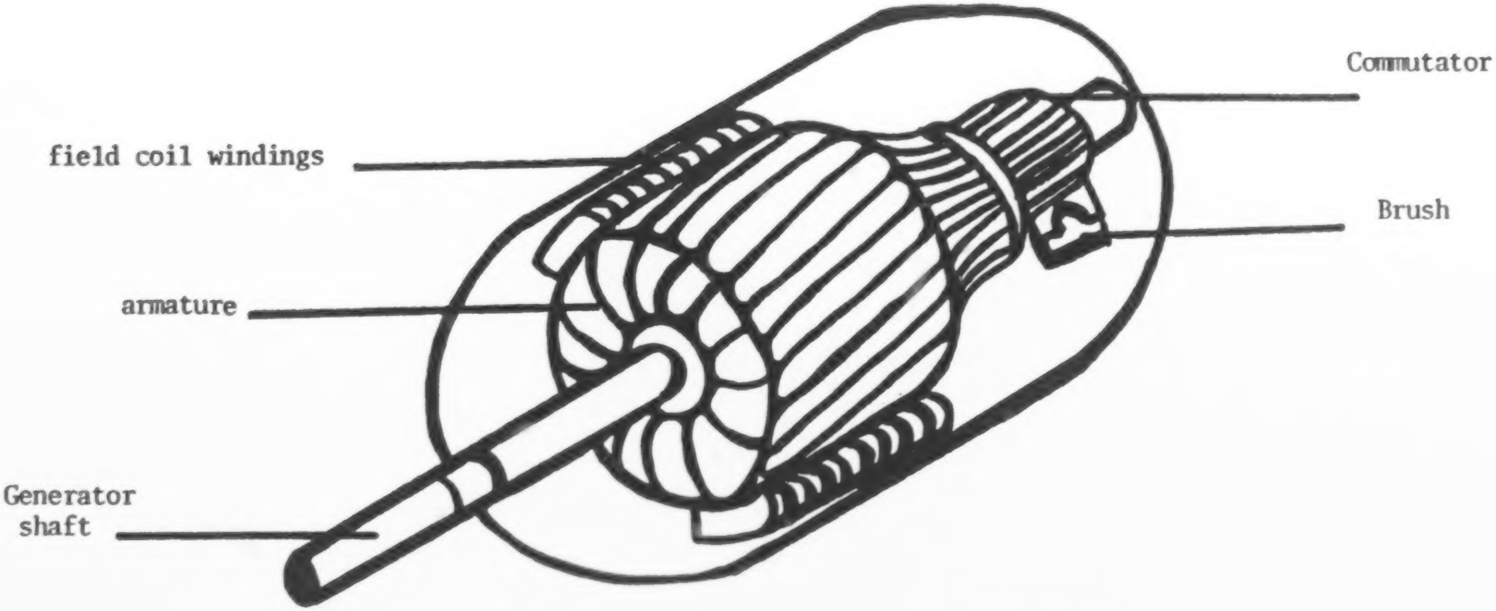
TRANSPARENCY #24A

TAIL VANE SAFETY MECHANISM

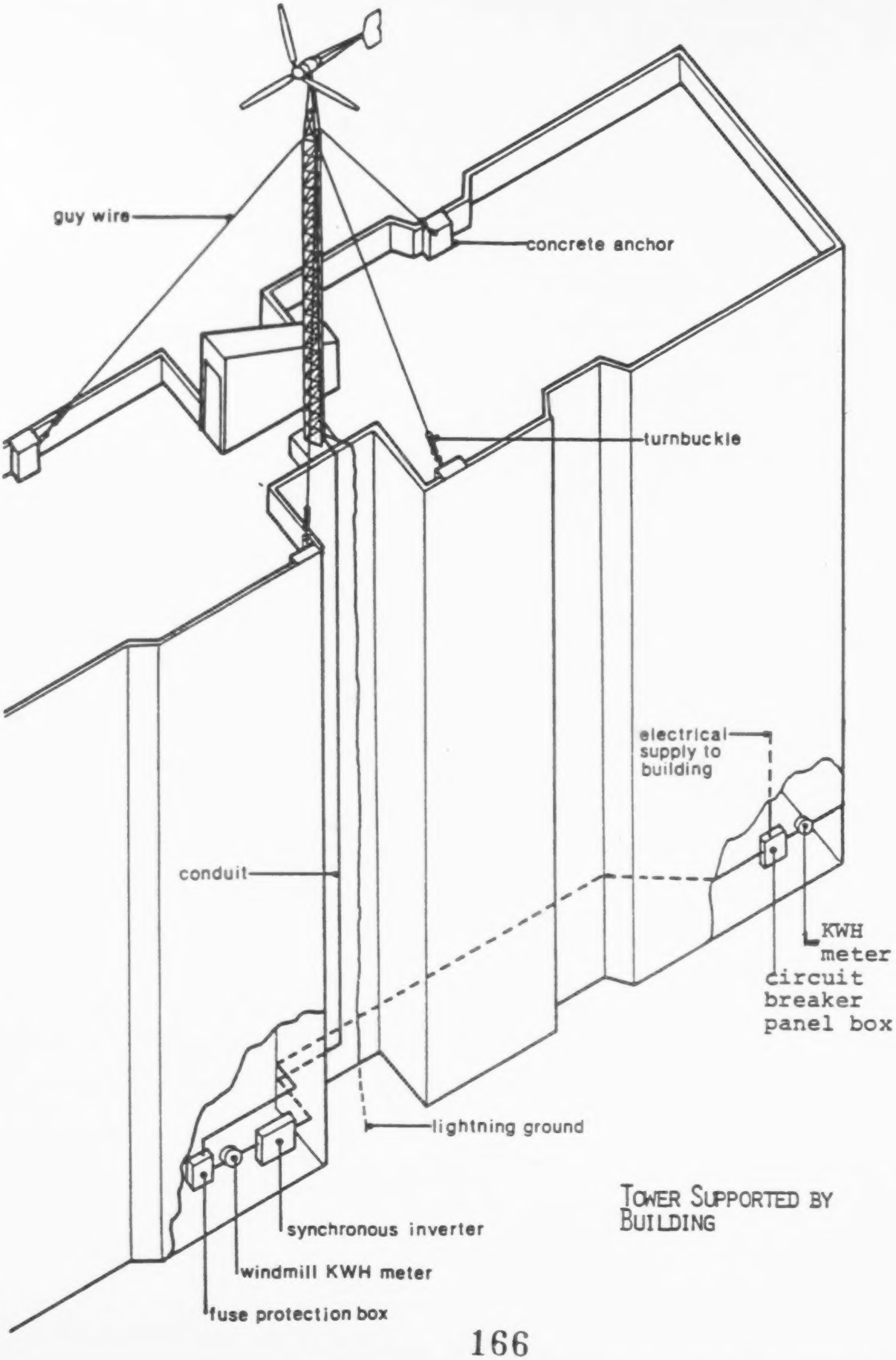

Wind
spring tension
tail vane in normal operating position.
Wind
Stop Chain
blades not spinning
Tail vane turned 90°


stop chain
winch chain
crank winch

TRANSPARENCY #25

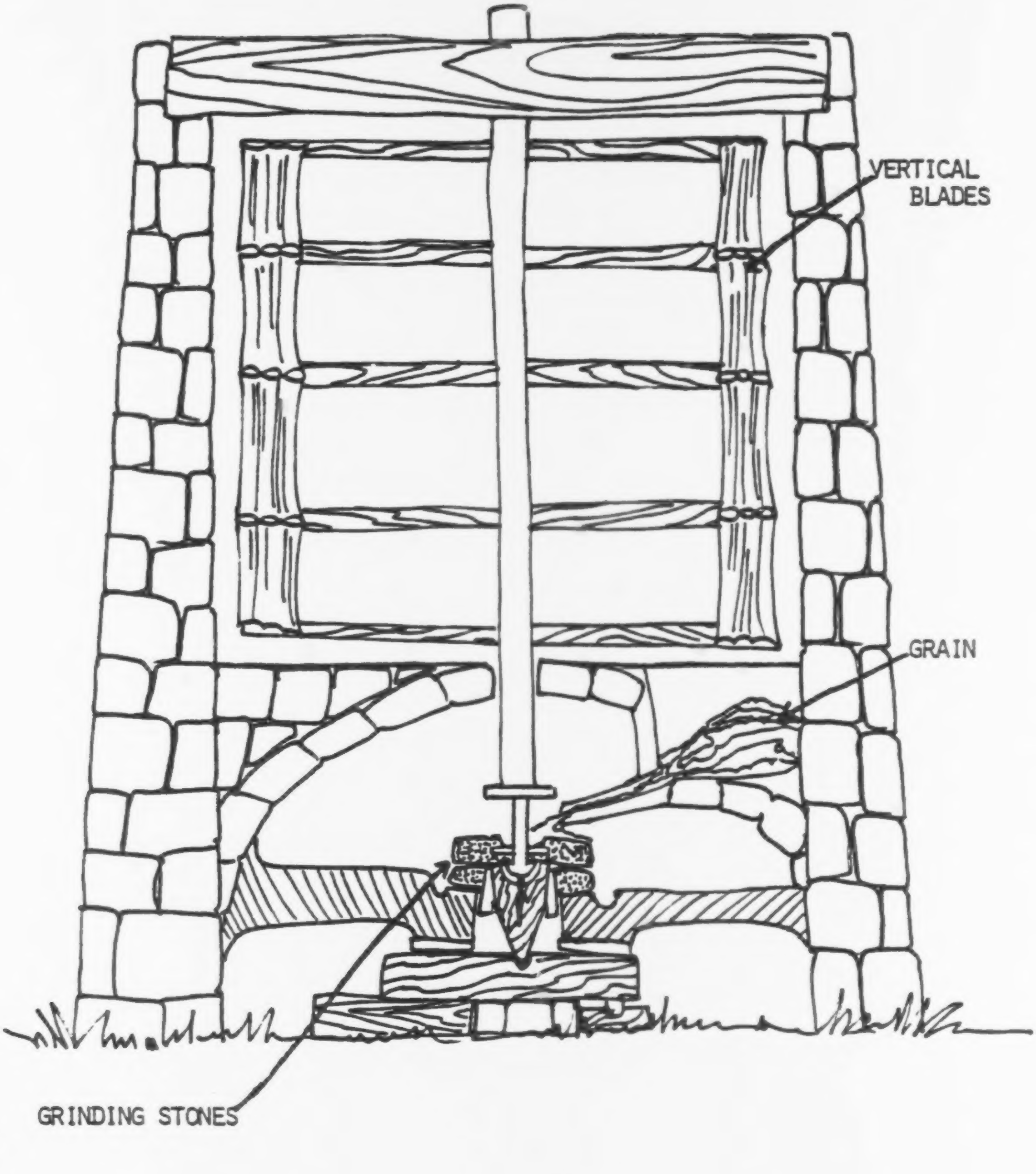

Commutator
field coil windings
Brush
armature
Generator shaft

GENERATOR BASICS

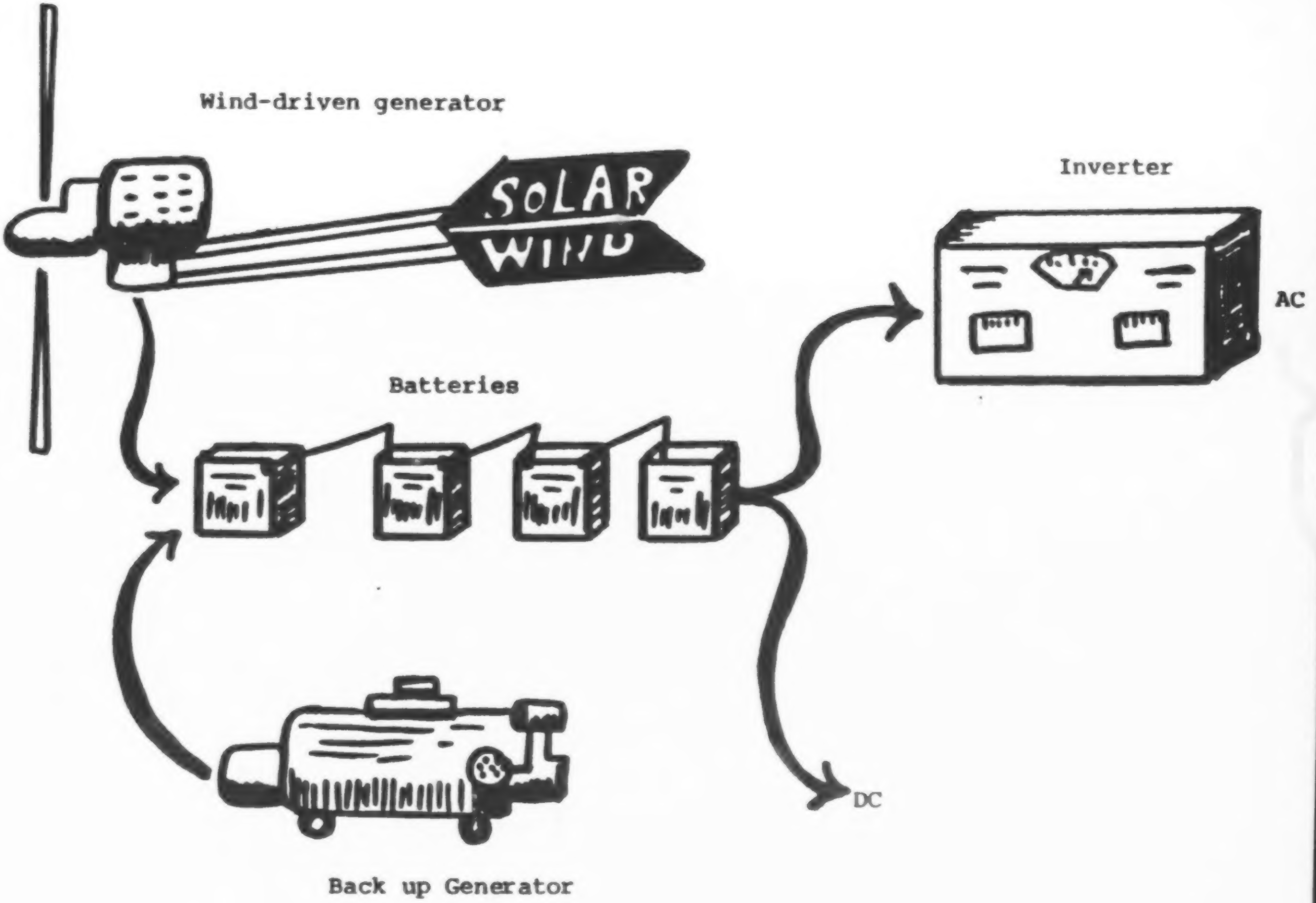

guy wire
concrete anchor
turnbuckle
electrical supply to building
conduit
KWH meter
circuit breaker panel box
lightning ground
synchronous inverter
windmill KWH meter
fuse protection box

TOWER SUPPORTED BY BUILDING

GRIST MILL


VERTICAL
BLADES
GRAIN
GRINDING STONES

TRANSPARENCY #28


Wind-driven generator
SOLAR
WIND
Inverter
AC
Batteries
DC
Back up Generator

Adapted from Electric Power from the Wind,
Clews, 1973.

TRANSPARENCY #29

APPLIANCES	POWER IN WATTS	CURRENT REQ'D IN AMPS AT 115V	TIME USED PER MO. IN HRS.	TOTAL KW HOURS PER MO.
Air Conditioner (window)	1,566	13.7	74	116.
Electric Blanket	117	1.5	73	13.
Broiler	1,436	12.5	6	8.5
Clothes Dryer (electric)	4,856	42.0	18	86.
Coffee Pot	894	7.8	10	9.
Dishwasher	1,200	10.4	25	30.
Freezer (15 cu. ft.)	340	3.0	290	100
Garbage Disposal	445	3.9	6	3
Heat (baseboard)	10,000	87.	160	1600.
Iron	1,088	9.5	11	12.
Light Bulb 75 watt	75	.65	120	9.
Oil Burner 1/8 HP	250	2.2	64	16.
Range	12,200	106.0	8	98
Record Player	60	5.0	.52	3.
Skill Saw	1,000	8.7	6	6.
Television (color)	332	2.9	125	42
Toaster	1,146	10.0	2.6	3.
Typewriter	30	.26	15	.45
Vacuum Cleaner	630	5.5	64	4.
Washing Machine	512	4.5	17.6	9.
Water Heater	4,474	39.	89	400.

Adapted from Electric Power from the Wind, Clews, 1973.